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NATO Committee on the Challenges of Modern Society

Prepared for

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CCMS SOLAR ENERGY PILOT STUDY:

REPORT OF THE ANNUAL MEETING

September 13-15, 1976
Copenhagen, Denmark

NATO/CCMS Report No. 54

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NATO Committee on the Challenges of Modern Society
CCMS SOLAR ENERGY PILOT STUDY
Solar Heating and Cooling Systems in Buildings

United States Pilot Country
Denmark Co-Pilot Country
France Co-Pilot Country

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This report contains the presentations made by representatives of participating countries during the third CCMS Solar Energy Pilot Study Meeting held in Copenhagen, Denmark, September 13-15, 1976. These presentations consisted of reports on national solar heating and cooling programs, summaries of special reports prepared during 1976 in accordance with the CCMS System Reporting Format, and previews of projects for which Special Format Reports will be prepared in 1977. Also included in this document are summaries of major topics covered during the general discussion session, as well as additional sections on pilot study activities.

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CCMS SOLAR ENERGY PILOT STUDY: REPORT OF THE ANNUAL MEETING

Copenhagen, Denmark
September 13 — 15, 1976

Edited by

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For the

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Energy Research and Development Administration
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EDITOR'S NOTE

This report contains the presentations made by representatives of participating countries during the third CCMS Solar Energy Pilot Study Meeting held in Copenhagen, Denmark, September 13-15, 1976. These presentations consisted of reports on national solar heating and cooling programs, summaries of special reports prepared during 1976 in accordance with the CCMS System Reporting Format, and previews of projects for which Special Format Reports will be prepared in 1977. Also included in this document are summaries of major topics covered during the general discussion session, as well as additional sections on pilot study activities. Those portions of the report not identified with an author were written by either R.W. Allen or S.B. Blum, using the notes of the meeting as a guide.

The editors wish to thank Prof. Vagn Korsgaard and Mr. Torben Esbensen, of the Technical University of Denmark, for the excellent way in which they organized and conducted the 1976 meeting. The assistance of Mr. Robert Emmons, formerly of the U.S. Embassy in Copenhagen, and Dr. Ingrid Rose is also appreciated.

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I. INTRODUCTION

NATO COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY

The Committee on the Challenges of Modern Society (CCMS) was founded in 1969 as an initiative of President Nixon to provide a "social dimension" to the North Atlantic Alliance. With the increasingly complex technological and environmental problems challenging industrialized societies–issues such as population, food and raw materials, air pollution, water pollution, energy, wastewater treatment, health care, disaster assistance, treatment of hazardous substances, etc. – the North Atlantic Alliance members recognized the need for an effective mechanism for sharing their economic and technological strengths in order to respond to the environmental and social challenges that confront them. CCMS has been instrumental in defining these challenges and in finding responses to them.

CCMS initiated the pilot study method, in which a lead country, in association with other interested countries, rather than an International Secretariat, conducts a project in an area of common interest. There are currently eleven CCMS pilot studies in which all NATO countries are actively participating. CCMS projects are open to interested non-NATO countries, and the Committee's projects have generated wide interest and participation around the world. Australia, El Salvador, Israel, Japan, New Zealand, the Philippines, Saudi Arabia, Spain, and Sweden are among those countries working with the NATO members on CCMS pilot studies.

CCMS has been recognized as an effective mechanism for meeting the imperatives of energy development and conservation, and it was the first international organization to deal with these problems. By late 1973, CCMS had initiated pilot studies in solar and geothermal energy, and shortly thereafter, in the rational use (conservation) of energy.

SOLAR ENERGY PILOT STUDY

The pilot country for the CCMS Solar Energy Pilot Study is the United States and the co-pilot countries are Denmark and France. The objective of the CCMS Solar Energy Pilot Study is the exchange of information on the solar heating and cooling systems programs and projects of each participating country so as to encourage the cost-effective and practical application of solar energy to heating and cooling in residential, commercial, industrial, agricultural, and public buildings. The key elements in this information exchange are:

1. The preparation and distribution of special reports, prepared in an agreed format, on certain projects in participating country;
2. The exchange of relevant and publically available reports concerned with solar heating and cooling systems in buildings; and,
3. The participation in meetings for the review of research and development programs, discussions and exchange of information and ideas.

The responsible agency in the United States for this pilot study is the U.S. Energy Research and Development Administration (ERDA). Dr. Frederick Morse, Chief of the R&D Branch in the Division of Solar Energy at ERDA, is the director of the CCMS Solar Energy Pilot Study. Assistance is provided by Dr. Redfield Allen and Ms. Sheila Blum of the CCMS Projects Office at the University of Maryland.

During October 1-4, 1974, representatives from seventeen countries met at the CNRS Solar Energy Laboratory at Odeillo, France, in the first annual meeting of the CCMS Solar Energy Pilot Study. The second annual meeting, attended by the representatives from twenty-two countries, was held in Palo Alto, California, from August 4-6, 1975. The third meeting of the CCMS Solar Energy Pilot Study was held September 13-15, 1976 in Copenhagen, Denmark. This report is a summary of that meeting.

II. SUMMARY OF THE MEETING

OBJECTIVES

The objectives of the 1976 CCMS Solar Energy Pilot Study Meeting were:

- To review the activities of the CCMS Pilot Study since the Palo Alto meeting and to discuss the activities planned for the coming year.
- To provide the CCMS Pilot Study participants with an up-to-date description of the status of the solar heating and cooling programs of the participating countries.
- To hear the report of the System Reporting Format Committee.
- To provide the participants with a summary of those projects for which Special Format Reports have been prepared and a preview of Special Format Reports that will be prepared during the forthcoming year.
- To hear the report of the Zero Energy House Group and to discuss the formation of additional project groups related to tropical and Mediterranean application of solar energy.
- To provide an open forum for the participants to exchange ideas on the activities of this CCMS Pilot Study. with emphasis on improving the overall effectiveness of this project.

AGENDA

CCMS SOLAR ENERGY PILOT STUDY MEETING

September 13-15, 1976
Copenhagen, Denmark

MONDAY, September 13

8.30 - 9.30	Registration
A.M. Session	*Chairman: Prof. V. Korsgaard, Denmark*
9.30 - 12.30	Introductory Remarks (V. Korsgaard) Objectives of Meeting (F. H. Morse) Report on Activities of Previous Year (F. H. Morse) Status of MOU (F. A. Harris) Report of System Reporting Format Committee (R. W. Allen) Report of the Zero Energy House Group (V. Korsgaard)
12.30 - 14.00	Lunch (hosted by the Danish Council for Industrial and Technical Research)
P.M. Session	*Chairman: Dr. M. Rodot, France*
14.00 - 16.30	Review of National Programs on Solar Heating and Cooling of Buildings of Participating Countries
16.30 - 17.30	Press Conference
19.30	Banquet at Divan 2 Restaurant, Tivoli Garden

TUESDAY, September 14

A.M. Session	*Chairman: Mr. J.-F. Robert, France*
9.00 - 12.00	Continuation of Review of National Programs in Solar Heating and Cooling of Buildings of Participating Countries
12.00	Lunch and Tour to the Euroc Solar House in Limhamn, Sweden

WEDNESDAY, September 15

A.M. Session	*Chairman: Mr. T. Esbensen, Denmark*
9.00 - 12.30	Presentation of 1976 Special Format Reports. Preview of Special Format Reports to be prepared in 1977
12.30 - 14.00	Lunch
P.M. Session	*Chairman: Dr. F. H. Morse, United States*
14.00 - 17.00	Possible New Mediterranean and Tropical Groups, CCMS Technical Meeting in Conjunction with next Meeting, General Discussion
17.00 - 18.30	Reception in the Zero Energy House at the Technical University of Denmark (hosted by the U.S. Embassy in Copenhagen and the U. S. Delegation)

HIGHLIGHTS OF MEETING

- Fifty-four delegates from nineteen countries plus the European Communities and NATO participated. Participating in the pilot study for the first time were representatives from Haiti, Iran, Mexico, Monaco and the European Communities.

- Sixteen of the nineteen participating countries, plus the European Communities, presented their national programs or summarized their country's present activities in solar heating and cooling systems in buildings. These reports showed an increase in the number of countries having national solar programs or an expanded number of active projects.

- Presentations of summaries of Special Format Reports, prepared in 1976 by 8 countries, were given.

- Previews of new Special Format Reports to be prepared during 1977 were given by 11 countries.

- Those assembled reaffirmed their desire to broaden the information exchange system by the designation, by each participating country, of an information agency or information specialist to assist in the dissemination of exchanged documents.

- A new group on Mediterranean climate applications of solar energy was formed.

WEDNESDAY, September 15

A.M. Session	*Chairman: Mr. T. Esbensen, Denmark*
9.00 - 12.30	Presentation of 1976 Special Format Reports. Preview of Special Format Reports to be prepared in 1977
12.30 - 14.00	Lunch
P.M. Session	*Chairman: Dr. F. H. Morse, United States*
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PILOT STUDY DIRECTOR'S PRESENTATION: A REPORT ON THE ACTIVITIES OF THE PREVIOUS YEAR

Frederick H. Morse
U.S. Energy Research and Development Administration
Division of Solar Energy

The CCMS Solar Energy Pilot Study, created to promote the sharing of information on solar heating and cooling systems in buildings, has now been in existence for over three years. Since the initiation of the Pilot Study in 1973, two annual meetings have been held - in Odeillo, France in 1974 and Palo Alto, California in 1975 - and we are now beginning the third annual meeting, here in Copenhagen.

The guidelines for participation in any of the CCMS pilot studies are specified in a Memorandum of Understanding. A draft Memorandum of Understanding concerning this cooperative information exchange program was discussed at the Odeillo meeting and was reviewed by designated agencies and governments of the countries which participated at the Odeillo meeting. Their comments were incorporated into the Memorandum of Understanding, which was sent to national capitals for signature by the appropriate government agencies in March 1975. The Memorandum of Understanding is included in Appendix F. To date the Memorandum of Understanding on solar heating and cooling systems in buildings has been signed by twelve countries: Australia, Belgium, Canada, Denmark, Federal Republic of Germany, France, Jamaica, Greece, Israel, Italy, United Kingdom, and the United States. Several additional countries have indicated their intention to sign the Memorandum of Understanding (MOU) and are expected to do so in the coming months.

Since the CCMS Solar Energy Pilot Study is open to all interested countries, whether or not they enter into a formal agreement by signing the MOU, contact has been established with several countries having new or existing solar energy research programs to encourage their participation in the Pilot Study.

The Memorandum of Understanding is based on the belief that international cooperation in the area of solar energy for heating and cooling processes in buildings will accelerate the introduction of cost-effective applications in the participating countries. It is an agreement to undertake a comprehensive exchange of knowledge about the design, the technical and economic characteristics, and the performance of solar energy systems and sub-systems developed and demonstrated in the course of the individual solar energy programs of the participating countries. The scope of the Memorandum of Understanding covers solar heating and cooling for residential, commercial, industrial, agricultural, and public buildings. The signatories of the Memorandum of Understanding, generally representatives of government agencies, designate a contact person through whom all reports and other documents will be exchanged. The signatories agree to expeditiously prepare and distribute special format reports on their solar heating and cooling projects and to distribute relevant and publically available reports in the same area. In addition to the exchange of special and general reports, the participating countries will participate in meeting for the review of research, development, and demonstrations programs and projects and for the discussion and exchange of ideas related to objectives of this agreement.

On August 4-6, 1975, the second annual Solar Energy Pilot Study Meeting was held in Palo Alto, California. The annual meeting provides a forum for review of the activities of the post year and a discussion of activities planned for the coming year. In addition, status reports on the solar heating and cooling programs of the participating countries are presented. The Palo Alto meeting was attended by delegates from twenty-two countries plus UNESCO. A System Reporting Format was reviewed and approved by the delegates. Representatives from nine countries presented brief previews of projects underway in their respective countries on which reports will be prepared this year in accordance with the System Reporting Format. The information exchange system was broadened to include an information specialist, who would receive one copy of each document exchanged, to assist in dissemination of reports exchanged under the Pilot Study. The activities of the Zero Energy House Group were reviewed and discussion held regarding formation of additional groups within the Pilot Study. It was the clear consensus of the delegates that the meeting was successful and beneficial.

The proceedings of the meeting* were edited and printed by the CCMS Projects Office at the University of Maryland, which assists the U.S. Energy Research and Development Administration (ERDA) with the Solar Energy Pilot Study. That report, which has been circulated to each contact person, contains a review of the CCMS Solar Energy Pilot Study and Reports on the national solar programs of those countries present at Palo Alto.

One measure of success for an international project such as this CCMS Solar Energy Pilot Study is the degree to which the international project meets and satisfies the programmatic goals of the participating counties. Thus, in addition to the obvious benefits resulting from a general information exchange or from a periodic review of one's own national program against the programs of many other countries, it is an optimal situation if the programs of the participating countries are broadened or accelerated by this cooperation. Since this CCMS Solar Energy Pilot Study is limited to information exchange, it is essential that a significant portion of this exchange be in such detail that each participating country will be able to effectively use the results of those reported projects that are relevant to its own program.

The performance of a solar heating and/or cooling system can, in general, only be understood if appropriate descriptions of the environment, components, the thermal characteristics, and the economic factors are provided. Since the exchange of information on these systems will be effective only if the information is adequately presented, it was agreed that a system reporting format should be established to effectively provide standardized information on the performance of a system or sub-system. Through a sequence of drafts, discussions, trial applications and evaluations, a system reporting format has been developed and was presented to the participating countries at the 1975 Palo Alto meeting.

The CCMS Solar Energy Pilot Study System Reporting Format for Heating and Cooling Systems in Buildings, approved at Palo Alto, was designed so that reports prepared in accordance with this format will provide, in concise form, all the significant information on the performance of a system or sub-system in a standardized manner. The twenty-two special format reports on completed solar installations which were to be prepared this year should have been or soon will be distributed by the orginating countries. Summaries of these reports will be presented later in the meeting. The special format reports are one of the most important elements of the Pilot Study, and the information contained in these reports is expected to be of considerable value to solar researchers. Reactions to these initial applications of the format will be solicited and possible modifications discussed at this meeting. It is of interest to note that the CCMS System Reporting Format was modified slightly and adopted for use by the International Energy Agency Solar Energy Working Group, as well as the National Building Council of one of the particiapting countries, and forms the basis of the system reporting format for the U.S. Solar Heating and Cooling Demonistration Program.

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* CCMS Solar Energy Pilot Study: Report of the Annual Meeting, Aug. 4-6, 1975, Palo Alto, California, UMD-4908-5.

In the area of exchange of general reports, the United States has distributed to the national contact persons ten reports and documents related to solar heating and cooling systems in buildings since October 1975. Included among these are reports on school solar heating experiments, solar workshop proceedings, National Bureau of Standards methods for rating solar energy equipment, the U.S. National Solar Energy Program, etc. All participating countries have been encouraged to identify and distribute significant general reports on heating and cooling systems in buildings.

The emphasis of each participating country's national solar energy heating and cooling program quite naturally reflects its specific building needs and climatic conditions. During the Odeillo meeting it became apparent that several groups of countries, having similar climatic conditions, were stressing similar applications. By drawing together experts from within the overall CCMS Pilot Study, who are working on a common task, it is possible to develop a very effective information exchange to supplement the more formal CCMS report exchanges. It is expected that solar energy researchers would benefit from close ties with their colleagues in other countries with similar climates and from discussion of and access to detailed system and sub-system performance information.

The Zero Energy House Group, chaired by Prof. Vagn Korsgaard of Denmark, was formed at the 1974 Odeillo meeting from among those participating countries working on solar-assisted low energy house projects for northern European climatic conditions. This group met twice in 1975 to review current projects related to energy conservation and solar heating systems in buildings in each of the represented countries and to discuss various aspects of energy conservation, measurement and instrumentation methods, performance of solar collectors, and storage systems. The countries participating in this project are Canada, Denmark, Federal Republic of Germany, The Netherlands, Sweden, United Kingdom, and the United States. This group is scheduled to meet again later this year or next year in Sweden, at which time there will be a detailed review of the first year of operation of several experiemental projects and a discussion of the performance data obtained.

At the 1975 Palo Alto meeting, interest was expressed in the possible formation of two new groups for tropical and Mediterranean applications of solar energy. We have assessed the interest of participating countries in the formation of such groups, and based on the favorable response, will attempt to establish these groups at this meeting.

It has been suggested that a CCMS Solar Energy Conference might be a valuable forum for the presentation of information on the performance of the many solar heating and cooling system projects undertaken by the participating countries. This would be an open technical meeting which would complement the annual solar energy pilot study meeting. The Federal Republic of Germany has tentatively agreed to host such a meeting in conjunction with the next annual meeting. This proposal will be discussed at this meeting.

In summary, several significant accomplishments have been achieved:

- An information exchange system has been established for exchange of reports on solar energy utilization among the participating countries which should and must benefit solar researchers in these countries.

- A system reporting format for reporting performance of systems and sub-systems in solar energy projects has been adopted, not only by this CCMS Pilot Study but by several countries for their national programs. Last year, nine countries indicated that they hoped to prepare special reports on twenty-two solar energy projects using the aforementioned format. We are looking forward to hearing about these projects later in this meeting.

- The Zero Energy House Group of the CCMS Solar Energy Pilot Study continues its activities, and we anticipate the formation of one or two additional groups at this meeting.

We look forward to continued progress in the CCMS Solar Energy Pilot study and continued cooperation in working to implement the potential of solar energy to help meet the energy needs of both industrialized and developing nations.

III. NATIONAL PROGRAMS: SOLAR HEATING AND COOLING SYSTEMS IN BUILDINGS

INTRODUCTION

One of the objectives of the CCMS Solar Energy Pilot Study meetings is the review of the status of the solar heating and cooling programs of the participating countries. The presentation and discussion of national programs and projects allow the participants to view their own activities against those of other countries and to note opportunities for closer cooperation or strengthening of their own program. The review of national programs and exchange of reports under CCMS has undoubtedly influenced the formation or expansion of solar heating and cooling programs in many of the participating countries.

A significant increase in the number of countries having national programs and/or expanded activities since the beginning of the pilot study was noted. At the 1974 Odeillo meeting only three of the seventeen countries represented had a national program in the area of solar heating and cooling systems in buildings, with an additional four countries reporting on active projects without the overall structure of a national program. Eleven months later, at the 1975 Palo Alto meeting, the number of countries with a national program had increased to ten, with an additional five having active projects without a formal national program. At the 1976 Copenhagen meeting, fourteen of the participating countries had national solar programs and six more had active projects. This changing status is summarized in Table 1. The emphasis of the present solar heating and cooling activities of the countries represented at the Copenhagen meeting is shown in Table 2. The full reports of the national solar heating and cooling programs follow these tables.*

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*Although Italy and Jamaica were unable to send a delegation to the Copenhagen meeting, updated reports on their solar heating and cooling programs were submitted for inclusion in this report.

Table 1

SUMMARY OF THE STATUS OF THE SOLAR HEATING AND COOLING SYSTEMS IN BUILDINGS PROGRAMS OF THE PARTICIPATING COUNTRIES*

COUNTRY	1974 (Odeillo) STATUS	1975 (Palo Alto) STATUS	1976 (Copenhagen) STATUS
Australia	No formal program – many projects underway.	No formal program – many projects underway.	No formal program – many projects underway.
The Bahamas	Not present.	No formal program.	Not present.
Belgium	Program being formulated.	Program initiated.	Program underway and several projects initiated.
Brazil	Observer.	Program underway involving many projects.	Not present.
Canada	Need for solar not established.	Program initiated and several projects started.	Program underway with increased funds and projects.
Denmark	Program underway involving several projects.	Program underway involving several projects.	Expanded program underway.
El Salvador	Not present.	No formal program.	Not present.
Federal Republic of Germany	Program initiated – several projects underway.	Program significantly expanded.	Program continues to expand significantly.
France	Program being formulated – several projects underway.	Program initiated and projects significantly expanded.	Program continues to expand significantly.
Greece	No formal program.	Program initiated.	Limited program underway.
Haiti	Not present.	Not present.	Observer.
Iran	Not present.	Not present.	Program initiated.
Israel	No formal program.	Program initiated and several projects started.	Program underway with initiation of new projects.
Italy	Program being formulated.	Program initiated – several industrial projects underway.	Not present.
Jamaica	Observer.	Program being formulated.	Not present. Limited program initiated.
Luxembourg	Observer.	Not present.	Program being considered.
Mexico	Not present.	Not present.	Observer.
Monaco	Not present.	Not present.	No formal program. Several projects underway.
The Netherlands	No formal program – several projects being initiated.	Program being formulated – additional projects started.	Program underway – several projects continuing.
New Zealand	Not present.	No formal program.	Not present.

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* This summary table was compiled by the University of Maryland CCMS Projects Office from the proceedings of the three meetings and is believed to be reasonably correct.

Table 1 (Continued)

COUNTRY	1974 (Odeillo) STATUS	1975 (Palo Alto) STATUS	1976 (Copenhagen) STATUS
The Philippines	Not present.	No formal program.	Not present.
Portugal	Not present.	No formal program.	Not present.
Saudi Arabia	Observer.	Program being formulated – several projects started.	Program initiated – several projects continuing.
Spain	Not present.	Program being formulated.	Program being formulated – several projects underway.
Sweden	Not present.	Program initiated – several projects started.	Program underway with several projects.
Turkey	Not present.	Not present.	Program formulated and projects underway.
United Kingdom	No formal program – several projects underway.	No formal program – additional projects initiated.	Not present.
United States	Program underway involving many R & D and demonstration projects.	Significant growth in program.	Significant growth continues.

Table 2

CURRENT EMPHASIS OF THE SOLAR HEATING AND COOLING SYSTEMS IN BUILDINGS PROGRAMS OF THE PARTICIPATING COUNTRIES

AUSTRALIA	Manufacture of solar water heaters continues to be directed at applications suitable for hot water services in individual homes and hotels. There is some export of collectors and technology, and growing interest in swimming pool heating. R & D at modest level undertaken in CSIRO and some universities with emphasis on industrial process heating applications to conserve oil. Demonstration installations in food processing industry being planned.
BELGIUM	Research on solar heating and cooling of buildings and solar water heating started at end of 1975. Two universities are involved: one studying water collectors, the other air collectors. Emphasis is on: (1) rational use of solar radiation data in order to predict thermal performance of solar collectors, (2) formulation of simulation programs, tested by comparison with outdoor measurements, and (3) study of different components of collectors. A solar house with collectors integrated in roof structure is also being studied.
CANADA	New funds ($700,000) are being used to improve solar data base; to aid construction of 14 single-family solar demonstration houses; and to fund 4-5 R & D projects on first generation solar space-heating hardware and systems. Feasibility study on solar space-heating continuing. Intensive monitoring to commence on 2 solar houses constructed in 1976; plans for intensive monitoring of 2 additional solar houses plus multi-unit residential building.
DENMARK	Government project related to solar heating of energy conserving buildings underway since August 1973. Zero energy experimental house in operation since Spring 1975. Related projects include: insolation analysis, system modeling, air-collector designs, phase-change energy storage. Government-supported solar energy information center recently established. Privately funded solar heated office building with seasonal storage under construction.
FEDERAL REPUBLIC OF GERMANY	By August 1976 industry-based and government cost sharing solar energy program expanded to 24 projects – 17 related to hot water supply and heating of buildings. Projects include: 4 solar heated homes; large solar heated outdoor public swimming pool; development of low-cost durable selective surfaces, and system studies. One large and several small firms are marketing hot water and heating systems.
FRANCE	Solar heating and cooling systems being developed on three levels. (1) CNRS program aiming at supporting fundamental research for practical development of solar systems, including bioclimatic study of comfort; systems analysis of housing; studies of components, and experiments on houses with south-wall collectors and air circulation. (2) Program conducted by "Plan Construction" (Ministere de l'Equipement) and independent organizations on long-range and efficient use of solar radiation for houses in temperate climates, including: testing stations in natural or artificial climates; high temperature collectors; storage; simulation; and architectural research. (3) Program of experimentation and demonstration led by "Delegation aux Energies Nouvelles" (Ministere de l'Industrie) and Plan-Construction comprising 35 projects, with funding exceeding 5 MF. Five of these projects, including solar heated homes, swimming pool, and CNRS-Odeillo (second phase) have been completed.
GREECE	Reflecting horizontal solar collector has been developed and evaluated. Portion of administration building of nuclear research center "Demokritos" will be converted to solar heating during winter 1976-77.
IRAN	In June 1976 utilization of solar energy officially integrated into national energy program. Council for Planning and Coordination of Solar Energy R & D established in Ministry of Energy. Government solar budget of over $2 million for 1976-77 to be used on heating and cooling buildings projects; industrial process steam; and total energy system for typical village.

Table 2 (Continued)

ISRAEL	Government supporting industry and academic institutions for research in areas of solar collector development, systems for larger installations, materials technology, and algae growth. Two large projects approved: one in industry for development of heating and cooling systems including hardware (3-5 year program); one on solar ponds as source of low-temperature heat in large quantities for heating and cooling of groups of buildings, desalination, and industrial uses.
ITALY	Government R&D program in solar energy got underway in the last half of 1976. Program includes contracts with EEC. Funding level in 1977 to be more than double 1976 level. Majority of projects involve fundamental areas of solar heating and cooling research such as collection of climatic data, studies of system components, solar cooling by night radiation, and systematic studies of solar heating suitable for typical urban dwellings. Additional projects initiated are a 15 KWE solar thermal conversion facility and photovoltaic cells for concentrated solar flux.
JAMAICA	Two university research projects initiated on use of solar crop dryers and low concentrating collector for air conditioning. Approval pending for research in solar cooking, irrigation, solar air conditioning and industrial process steam.
LUXEMBOURG	Solar energy program being considered. Interest shown in domestic hot water and, for the long term, in solar assisted heat pumps.
MONACO	Local industry is developing solar systems to replace or supplement other forms of energy for dwellings, offices, hospitals and swimming pools. Projects include: 3 types of flat-plate collectors; 2 types of concentrating collectors, 2 greenhouse heating projects using parabolic reflectors and flat plate collectors; 1 project on anti-freeze and corrosion resistance.
THE NETHERLANDS	Government sponsored program emphasizing development and demonstration of solar heating and cooling systems. Projects at universities and research institutes include work on three energy-conserving solar-heated low income housing units; solar-heated home; solar-heated laboratory; solar-heating system optimization studies; solar-cooling; advanced collectors; and collection of solar radiation data.
SAUDI ARABIA	Two universities active in data collection and evaluation of solar energy systems. Solar energy department as part of national nuclear research center announced. King Faisal Foundation plans to support new solar heating and cooling project.
SPAIN	Work on solar heating and cooling of buildings carried out by private industry, government institutions and within international programs such as IEA. Laboratory for performance testing of flat-plate collectors in operation, approximately 10 differenct flat-plate collectors are commercially available. Privately promoted solar-assisted high-rise office building under construction and plans for construction of experimental solar houses and apartment buildings under consideration.
SWEDEN	Solar program to be revised March 1977 as one basis for energy policy decisions to be made in Spring 1978. Tap water heating first option of interest since small quantity of Swedish-developed and manufactured solar water heaters will soon be commercially available. Two solar-heated demonstration houses have been monitored; applications for multi-family housing foreseen in two years. Intensive international cooperation being pursued.

Table 2 (Continued)

TURKEY	Solar energy program formulated as part of national energy program and 5-year plan. Program will be coordinated by Ministry of Energy and Natural Resources and involve several government organizations and universities. Two major projects recently initiated, solar-heated house and establishment of a solar energy research center. Several commercial firms manufacture water heaters. Scientific research underway at universities and Turkish Scientific Research Council on insolation measurements, solar water heaters, greenhouses, crop drying, and solar cells.
UNITED KINGDOM	The UK Section of the International Solar Energy Society published a major report on the potential for solar energy utilization in the UK and a government response to this is awaited. Some thirty firms now offer solar water heating equipment and a few houses with solar heating panels and heat pumps are under construction. The projects reported in 1975 continue to progress but no performance reports have been published.
UNITED STATES	Federal program in solar heating and cooling of buildings has four main elements: residential demonstrations; commercial demonstrations; development in support of demonstrations; and R & D – all directed at stimulation of industry capable of providing solar systems on wide scale. Over 150 residential solar systems supported in past year with several times that built with private funds. 34 commercial buildings funded, bringing total to over 50. R & D program now has over 70 projects on collectors, storage, heat pumps, cooling, systems and controls. Emphasis of R & D program continues to be cost-effectiveness. Supporting activities continue on information dissemination, performance criteria and standards, and component and system integration and testing.

SOLAR ENERGY UTILIZATION IN AUSTRALIA

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INTRODUCTION

Manufacture of solar water heaters continues to expand, annual production figures in terms of collector area being: 1973 – 8,400m^2, 1974 – 11,600 m^2, and 1975 – 25,330m^2. These are used almost entirely for solar water heaters for residential and commercial applications but the interest in solar energy is such that industrial applications are now being intensively studied.

The Australian Senate Standing Committee on National Resources has commenced an enquiry into solar energy and has received submissions from a large number of interested organizations and individuals. Members of the public can attend the Committee's hearings and can obtain copies of documents which are submitted to it.

The Institution of Engineers, Australia, has set up an Energy Task Force to examine and report on all forms of energy in relation to their significance to the Australian economy and hopes to report by the end of 1977. Some 12 working parties have been set up in specialized areas including solar energy, and it is expected that each of the working parties will produce reports which will be presented at an Energy Conference to be held in July 1977. Annual expenditure on research and development in 1974-75 was $675,000 comprising $549,000 in CSIRO and $126,000 in universities from ARGC grants.

An important recent development has been the establishment of techniques for measuring thermal performance of individual collectors in such a way that the heat generation of collectors in an installation can be predicted. This enables solar heat generating systems to be designed with confidence, and an outline of the procedure is given in the following section.

HEAT OUTPUT OF SOLAR COLLECTORS

The following four steps can be taken to predict an expected heat output for a solar collector in any particular location:

1. Measure the thermal collector characteristic. Experimentally determine the dependence of the collection efficiency on the mean water temperature in the collector, ambient temperature, solar radiation, and as far as is possible, on wind as well.

2. Assemble the meteorological characteristics of various locations so that solar radiation, ambient temperature and wind velocity at hourly intervals can be stored on magnetic tape and accessed by suitable computer programmes.

3. Predict hourly values of solar radiation on planes inclined at any angle and oriented in any direction, using as input, measured values of insolation on a horizontal surface for each location under consideration. This is necessary because it would be impracticable to measure over a period of years, the insolation on every conceivable plane in which collectors may be mounted.

4. Predict heat generation for collectors for specific locations and any angle of inclination and orientation. Computer programs are available which will print out the average daily heat produced month by month and annually for any temperature of the water entering the collector.

MEASUREMENT OF THERMAL COLLECTOR CHARACTERISTIC

This measurement requires a simple outdoor test rig which can take a standard commercial collector, measure its heat output for a known water inlet temperature and flow rate and at the same time measure the incident radiation on the plane of the collector. In addition, facilities should be available for measuring the effect of wind on collector heat output. Such test rigs are available at the CSIRO Division of Mechanical Engineering at Highett, at its Field Station in Griffith, New South Wales, and at the University of New South Wales.

METEOROLOGICAL DATA

The data required for determining the heat generation of a solar collector are simultaneous values of solar radiation on the plane of the collector, ambient temperature, and wind velocity hour by hour for a period of several years for the location in question. The only measurements available for solar radiation on a plane inclined at latitude angle facing north are those measured at Highett since 1966. These values, together with Meteorological Bureau measurements of ambient temperature and wind velocity are stored in the CSIRO computer system, and can be used for the preparation of collector heat tables. For other locations, or for other angles of inclination and orientation of the collector, it is necessary to predict the insolation on the plane of the collector using measured values of insolation on a horizontal surface.

PREDICTION OF HOURLY INSOLATION ON THE PLANE OF THE COLLECTOR

In Report No. S.E.S. 75/4 entitled "The Determination of Hourly Solar Radiation Incident upon an Inclined Plane from Hourly Measured Global Horizontal Insolation" by J. W. Bugler, an atmospheric model is described which enables the Meteorological Bureau's records of insolation on a horizontal surface to be used to provide details of the insolation on a surface inclined at any angle and oriented in any direction.

The available insolation on a horizontal surface measured by the Bureau of Meteorology is now stored in the CSIRO computer system, and can be operated on in the manner described in S.E.S. Report No. 75/3 "Global Horizontal Solar Radiation For Australian Locations Stored in the CSIRO Cyber 7600 System: the Data and Method of Retrieval" by J. W. Bugler. The 20 stations for which this information is available is listed on page 4 of that report. Before it can be used in one or other of the computer programmes, any gaps in the records must be filled in. This has only been done (as at February 1976) for Melbourne, Williamtown near Sydney, and Alice Springs. In addition, values of ambient temperature and wind velocity have to be added, and this has only been done for Melbourne and Williamtown.

As an example of the interesting information which can be obtained from these solar radiation records and Program PRERAD, the program which predicts radiation on surfaces of varying inclination and azimuth, tables have been prepared of monthly average values of daily insolation for Melbourne and Williamtown. These show that the yearly average insolation on an inclined surface is relatively insensitive to inclination up to one and a half times latitude angle and to azimuth up to +45° measured from due north. Even for a plane at latitude angle, azimuth +90 (due east) the year average is 12.7MJ/m^2 compared with 15.0 at latitude angle facing due north and 14.3MJ/m^2 on the horizontal surface. Such tables are not an accurate indication of the heat generation from solar collectors, but do serve to indicate trends. Bugler's atmospheric model and his PRERAD Program fill a gap in our radiation input data for the preparation of collector heat tables, but there has not yet been an opportunity to compare the accuracy of their predictions with actual measurements made on surfaces of different inclination and orientation. Nevertheless good agreement has been found between the measurement at Highett on a 38° plane and the predictions made from horizontal insolation using Program PRERAD.

COLLECTOR HEAT TABLES

Heat tables for a single glazed collector operating in Williamtown have been produced using Program SOCOFI. This program uses the data provided by the Program PRERAD, together with wind and temperature data, to calculate the average daily heat output in MJ/m^2 d of any collector whose characteristic efficiency curve and dependence on wind speed is known. The collector is assumed to be operating in a situation where the fluid flow and inlet temperature are fixed and the temperature of the outlet is at least 1°C above the inlet temperature. Values of heat output are calculated at 10°C increments between 25°C and 95°C inclusive. The fluid flow through the collector is one input statement to the program and, typically, tables are prepared for a water flow of 15 ml/s m^2. Other runs of this program show that the heat output is not sensitive to flow rates in the region 5-25 ml/s m^2.

REPORT ON THE BELGIAN SOLAR ENERGY PROGRAM

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INTRODUCTION

The solar energy R & D program which was presented at the Palo Alto meeting was initiated in June 1975 and research began at the end of last year. The solar energy program is composed of three parts:

1. Thermal conversion
2. Photovoltaic conversion
3. Economic study

THERMAL CONVERSION PROGRAM

The objectives of the Thermal Conversion program are:

- To determine the optimum design for solar collectors in Belgium
- To optimize, on a technical and economical basis, solar systems for hot water supply and heating of buildings, and swimming pools
- To design integrated solar collector roof structures.

The working program to reach this goal includes:

- Field tests on different types of flat plate collectors
- Determination of static and dynamic characteristics
- Formulation of mathematical models
- Studies on different types of glass covers – test and simulation
- Analysis of the static and dynamic behavior of a complete solar heating system (collectors, storage, heat load and regulation)
- Definition from the data available at the IRM (Royal Institute of Meteorology) of a set of solar data usable in a simulation program (Belgian reference year)
- Study of an acceptable Belgian solar house (The construction of the house is planned for the end of the research program)
- Study of a heat storage system using a chemical reaction.

The research teams involved in the project are:

- The Faculte Polytechnique de Mons (F.P. Ms.)
- The Katholiek Universiteit te Leuven (K.U.L.)
- The Royal Institute of Meterology (I.R.M.).

The F.P.Ms. is mainly concerned with solar collectors using a liquid as transfer fluid, and the K.U.L. is studying the behavior of air solar collectors. The Department of Architecture of the F.P.Ms. will design the solar house.

TESTS AND SIMULATION

In addition to developing sophisticated analytical models for predicting performances of solar collectors and in order to check their validity, two outdoor test facilities have been constructed: In Mons, a facility for testing liquid flat plate collectors is in operation, and in Heverlee, air collectors are under investigation.

The experimental facility consists of collectors, heat transfer flow loops and measuring instruments. The recorded measurements allow the calculation of the efficiency of the collectors (instantaneous, daily or according to the NBS test procedure).

SOLAR RADIATION DATA

On its small territory (30.150 km^2) extending in latitude from 49°54′ to 51°16′, Belgium has a fairly dense concentration of meteorological stations where many of the primary necessary solar data have been recorded since 1951 and are available every half hour or every hour.

The main station is located in Uccle (Brussels) and is equipped with:

- Pyrheliometer for direct radiation
- Pyranometer for global and diffuse radiation
- Campbell stokes heliographes
- U.V. radiation (290-390 nm) measuring instruments
- Spectral measurements of global solar radiation at given wavelengths (451-490-650-710 and 830 nm).

In addition, there are 4 stations where the global solar radiation and the duration of insolation are being measured and 21 stations were the duration of insolation is recorded.

One of the first tasks of the research teams was to make rational use of the available solar radiation data in order to predict performance of solar systems in simulation programs. From statistical studies over 20 years of recorded solar data, our metorological institute has shown that for 10 day periods, the angstrom relationship

$$\frac{G}{G_o} = a\frac{s}{s_o} + b$$

where G is the global solar radiation for an insolations period s
G_o is the global solar radiation for clear sky conditions
s_o is the maximum possible duration of insolation
a and b are constants determined from the analysis of the data was valid

was valid.

Furthermore, it can be shown that the same factor $\frac{s}{s_o}$ can be used to determine the direct component of solar radiation E for the same period of time. Thus we can write:

$$E_s = E_o \left(\frac{s}{s_o}\right) b$$

where $n = .0055_\delta + 1.105$
δ = solar declination
E_s = direct solar radiation for the hours of bright sunshine
E_o = direct solar radiation for the maximum hours of bright sunshine.

Therefore $$D_s = G_o \left(a\frac{s}{s_o} + b\right) - E_o \left(\frac{s}{s_o}\right) n$$

$$G_o = E_o + D_o$$

where D is used for the diffuse component of the radiation. E_o and D_o are functions of time, day of the year, turbidity factor, latitude and longitude of the site, and their calculation is well known.

In order to test the method of calculation, it has been applied (1) to the observations made in Brussels for which the observed and calculated values of G, E and D are shown in *Table I* (over a 15 year period) and (2) to those made in Alger (over a 9 month period), as shows in *Table II*. To determine the total radiation on a tilted surface, the angular correction for the direct component is well known and the correction factor for the diffuse component has been chosen to unity (waiting for a more satisfying correction factor for covered sky). For different periods of time, polar diagrams giving total radiation versus orientation and slope have been drawn *(Fig. 1)* and can be used for preliminary estimates in projects.

This is certainly a method for determining from simple measurements (hours of sunshine) the amount of energy available in a given geographical site on any oriented surface, but the collector analysis and the tests we have been conducting so far have shown that the use of mean values (10 day periods) could not yield sufficiently accurate results for an optimization study. For this reason we are working towards the construction of a reference year and are participating in the working group "climatic conditions and reference year" of the CCMS Rational Use of Energy Pilot Study.

Table I

G_{cal}, E_{cal}, D_{cal} are calculated values in J/cm^2

G_{obs}, E_{obs}, D_{obs} are the observed values in J/cm^2

	s/s_o	G_{obs}	G_{cal}	$\frac{G_{obs}}{G_{cal}}$	E_{obs}	E_{cal}	$\frac{E_{obs}}{E_{cal}}$	D_{obs}	D_{cal}	$\frac{D_{obs}}{D_{cal}}$
J	0,29	239	237	1,01	73	73	1,00	166	164	1,01
F	0,27	439	433	1,01	138	135	1,02	301	298	1,01
M	0,39	849	828	1,03	341	335	1,02	508	493	1,03
A	0,45	1333	1310	1,02	576	575	1,00	757	735	1,03
M	0,46	1675	1653	1,01	715	720	0,99	960	933	1,03
J	0,47	1834	1803	1,02	833	781	1,07	1001	1022	0,98
J	0,40	1590	1630	0,98	602	626	0,96	988	1004	0,98
A	0,39	1339	1378	0,97	504	535	0,94	835	843	0,99
S	0,51	1143	1132	1,01	538	540	1,00	605	592	1,02
O	0,43	660	660	1,00	272	281	1,06	388	379	1,02
N	0,22	264	278	0,95	69	73	0,95	195	205	0,95
D	0,18	162	168	0,96	39	36	1,08	123	132	0,93

Table II

	s/s_o	G_{obs}	G_{cal}	$\frac{G_{obs}}{G_{cal}}$	E_{obs}	E_{cal}	$\frac{E_{obs}}{E_{cal}}$	D_{obs}	D_{cal}	$\frac{D_{obs}}{D_{cal}}$
A	0,74	2468	2324	1,06	1846	1794	1,03	622	530	1,17
S	0,71	2037	1976	1,03	1420	1468	0,97	616	508	1,21
O	0,58	1277	1335	0,96	828	820	1,01	449	515	0,87
N	0,70	1171	1160	1,01	764	778	0,98	407	382	1,07
D	0,82	1034	1042	0,99	770	775	0,99	264	267	0,99
J	0,50	864	828	1,04	506	419	1,21	358	409	0,88
F	0,71	1380	1402	0,98	926	990	0,94	454	412	1,10
M	0,57	1500	1536	0,98	904	981	0,92	596	555	1,07
A	0,57	1942	1923	1,01	1442	1349	1,07	500	574	0,87

So far, with the collector analysis and the experimental study we have conducted, we have been able to compare different methods of calculation for predicting the performances of solar collectors and to make a choice among them. This result has been obtained by studying the static and dynamic behavior of collectors under various climatic and operating conditions.

In order to determine which set of meteorological data must be used in the construction of a reference year, we have focused our attention on the influence of the climatic parameters such as

- frequency of solar radiation
- ratio direct/diffuse radiation
- use of mean values
- ambient temperature

GLASS COVER WITH I. R. COATING

Working with the glass industry, we have studied the influence of the transmission, absorption and reflection factors of glass covers with low emissivity layers (SnO_2) on the collector efficiency.

The spectral characteristics of the layers, the angular variation of the transmission and absorption coefficients have been determined, and tests and calculations on differents combination of covers are made *(Figs. 2, 3, 4)*.

SOLAR HOUSE

At the end of the research program, a solar house will very likely be built. The research group at the F.P.Ms., working with the department of architecture, will study the solar heating system and produce a detailed design of the house.

This project is under way. The problem connected to the integration of solar collectors in the roof structure is being studied. The design of a water-tight double glazed roof is completed, and a model has been built in order to test its effectiveness and its durability.

STORAGE OF ENERGY – USE OF THE HEAT OF REACTION OF CHEMICAL COMPOUNDS

The problem of energy storage in solar applications is a crucial one in the Belgian climatic conditions. Thus far the cost of the stored kcal in conventional storage systems (which imply heavy thermal insulation) are too high, and the possibility of using chemical reactions in order to store energy is being studied.

The main objective of the project is to find two compounds A and B which can, by mixing, react exothermally as

$$xA + yB = A_x B_y$$

and liberate the heat of formation any time heat is needed, the decomposition of the product A_xB_y being obtained by supplying thermal energy (solar or other) when this energy is available and heat is not needed.

The first task will be a search for chemical compounds such that

- The storage capacity is greater than $\frac{1 Gcal}{m^3}$
- The storage of A and B at room t° is feasible
- The decomposition process takes place in the range 80 to 120°C
- A, B and A_xB_y must have good stability, low toxicity and low cost.

This phase implies a bibliographical search and a thermodynamic analysis of the different compounds having the required properties, followed by an experimental work composed of calorimetric studies of the compounds, a thermodynamic study of the reaction and a study of the separation process.

PUBLIC PROJECT

The Province of Namur is planning the construction of a vacation village and a sports complex in a 450 ha area in the village of Chevetogne. It will include an olympic size open-air swimming pool, a 16x10 m indoor swimming pool, an omnisport hall (1500 m^2), lodging ($\simeq$ 700 m^2) and cafeteria.

The study of the heating systems of the swimming pools, of the building and of the domestic hot water by solar energy or by solar assisted heat pumps, has been made by the Engineering Office ATRAC in Brussels.

In all, about 2500-3000 m^2 of solar collectors will be installed in Chevetogne. The technical study will be completed in September 1976. The construction of the olympic swimming pool is expected during 1977, the sport hall and the indoor swimming pool in 1978, and the lodging and restaurant in 1979.

PRIVATE PROJECTS

Many individuals have asked their architect to build solar houses. It is encouraging to see the public demand for solar energy but is unfortunate that architects have to propose solutions today when there is still a terrible lack of technical knowledge on the systems and their life time, and a few bad experiences would inevitably result in publicity which could damage the future of solar energy.

INTERNATIONAL COOPERATION

Belgium participates in the following international working groups:

NATO-CCMS	Solar Energy Pilot Study
NATO-CCMS	Climatic conditions and reference year of the Rational Use of Energy Pilot Study.
IEA	Working groups on solar energy and subprojects 2, 3, 4 and 5
EEC	Working groups on solar energy. Participation in the round robin test of solar collectors distributed by the JRC at ISPRA.

A Belgian section of ISES has been created this year

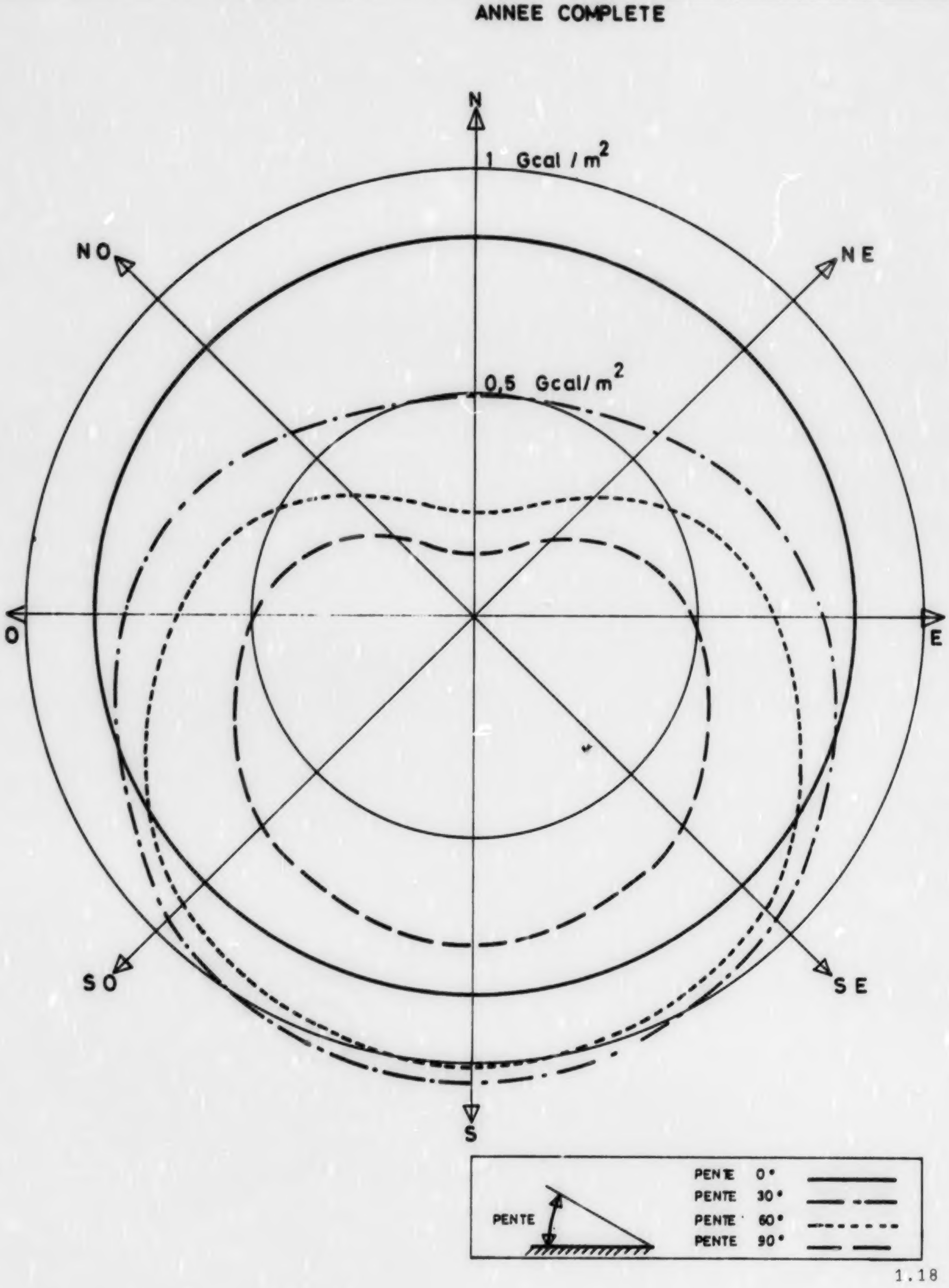
ANNEE COMPLETE
N
1 Gcal / m2
NO
NE
0,5 Gcal/m2
O
E
SO
SE
S
PENTE
PENTE 0°
PENTE 30°
PENTE 60°
PENTE 90°
1.18

Figure 1

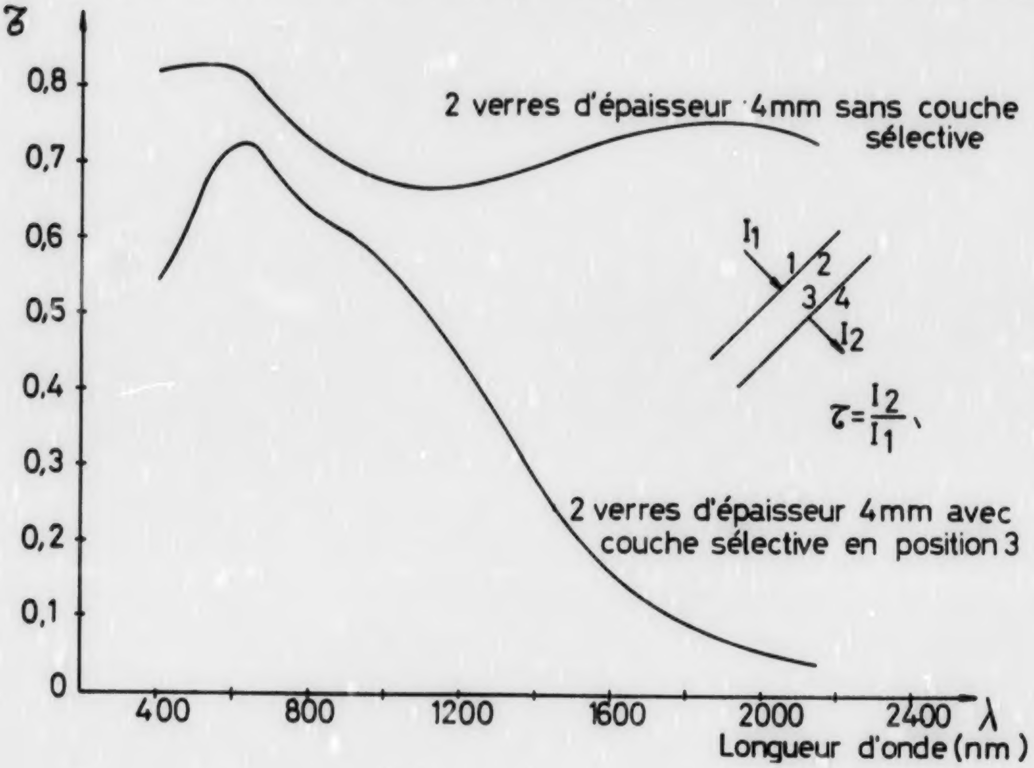

Figure 2

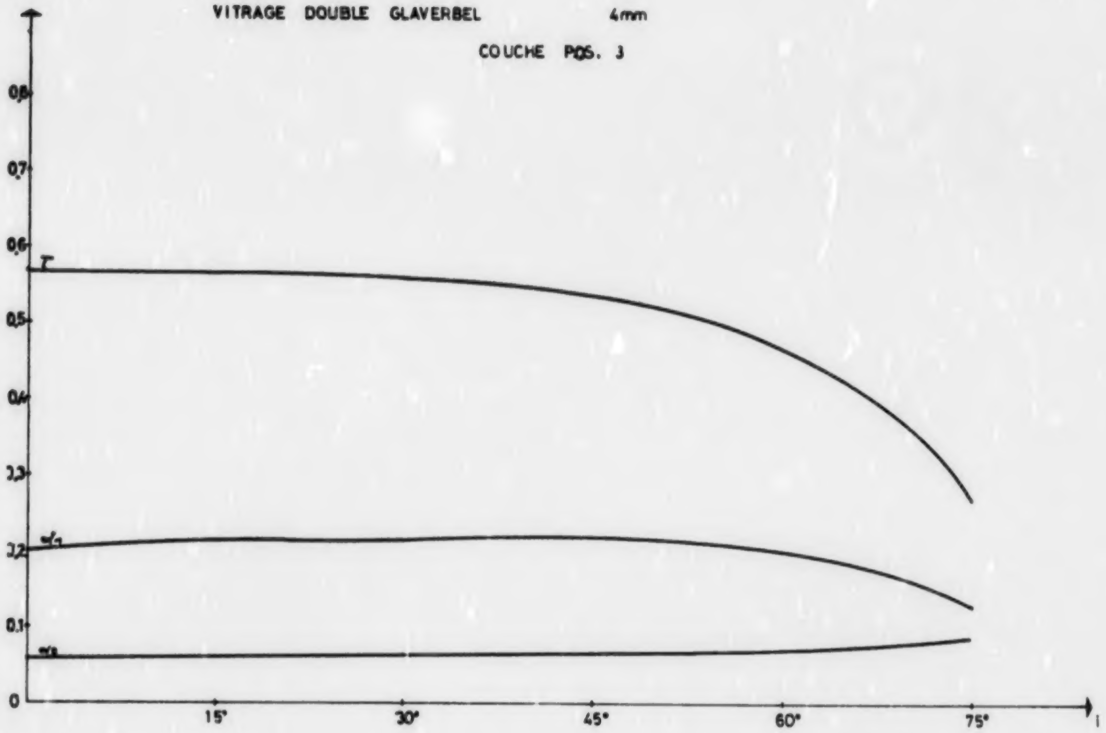

Figure 3

REPORT ON THE CANADIAN SOLAR ENERGY PROGRAM

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INTRODUCTION

At this time last year, activity related to solar energy development in Canada was curtailed by the absence of funding. Solar activity consisted of the ongoing solar radiation field measurements by the Atmospheric Environment Services; a feasibility study on solar heating of buildings in Canada by the University of Waterloo; a number of solar-heating demonstration projects initiated by the Ministry of State for Urban Affairs; and the construction of a very small number of private solar-heated houses.

The level of activity has been increased considerably this year by the introduction of about $700,000 by the Federal government, and an equivalent amount by the provinces and the private sector.

CURRENT ACTIVITIES

The current status of those activities reported last year are as follows:

Atmospheric Environment Services

Part of the Federal funds will be used by AES to provide weather and solar radiation data for the major urban centres in a format usable by building heating engineers. This will involve a modest increase in the number of weather stations measuring solar data; the development of a method for inferring insolation data for areas with no measured solar data; and the development of a reliable method for translating solar radiation falling on a horizontal surface, to radiation falling on sloped surfaces.

Waterloo University Feasibility Study

The first phase of the study, the development of a suitable computer program for simulating the behavior of solar space-heating systems, is now complete. Two reports describing the simplified program for simulating air systems with short-term storage, and water systems with short-term and seasonal storage were sent to the CCMS Solar Energy Pilot Study contact persons. The second phase, which will attempt to determine economic viability of solar heating in seven Canadian cities, should be completed this Fall.

Canadian Urban Demonstration Projects (Ministry of State for Urban Affairs)

(a) The status of the three houses for which CCMS special format reports were to be prepared was described in the session on Special Format Reports.

(b) The Ark for Prince Edward Island is now nearing completion and should be operational this fall. It features four distinct interior spaces:

living area of $116 m^2$
aquaculture/greenhouse of $242 m^2$
laboratory of $14 m^2$
barn of $4 m^2$

The heat collected in the greenhouse will be stored in the fish tanks and in a separate crushed rock storage unit of $90\ m^3$. The living area will be partially heated by a solar system consisting of $79\ m^2$ of water-heating collectors and a storage unit of $91\ m^3$ of water.

(c) Of the four prototype houses for the Quebec Indian Communities started last year, one is now completed, two should be completed this fall, and one will not be built. The completed house, called the "Cote Nord" prototype, has $98\ m^2$ of living area, $47\ m^2$ of vertical air-heating collectors and a storage unit of $33\ m^3$ of crushed rock. Supplementary heating is with a wood stove.

(d) A project not reported last year but initiated under the Urban Demonstration Project is the solar demonstration on the Manitoba Legislature Building. Four collector arrays, each $23\ m^2$ in area, are mounted on the roof of the Legislature Building. The collected energy will be stored in two water tanks with a total volume of $27\ m^3$, and will be used to heat an unoccupied area of the building. The system should be operational this winter.

NEW PROJECTS

The solar heating activity initiated this year can be summarized as follows:

Federal Program

In addition to supporting the foregoing projects, a funding program of $550,000 was initiated in the spring of this year in support of solar heating of buildings. The program contains four sub-sections covering demonstration houses, monitoring of solar-heated houses, research, and commerical development of solar heating hardware.

Contracts will be signed this month for the construction of 14 solar-heated single-family dwellings across Canada (See *Table I*). Financial support will be for the design, hardware purchase and installation of the solar heating system. Single-family dwellings located in housing developments were selected for maximum dispersal and visibility, and not because they were the ideal application of solar heating. More appropriate applications will be demonstrated next year. The solar systems demonstrated will include six water systems, six air systems, one heat-pump augmented water system, and one remote-located solar air-heating furnace. Short-term storage will be used in all demonstrations. The demonstration systems are to be operational by the spring of 1977, and will be monitored the following heating season.

The research and development proposals are now being reviewed and four or five contracts will be let this fall. Limitation of funds dictates that support will likely be given to proposals that encourage the establishment of first-generation solar-heating technology in Canada. Long-term research on solar heating as well as on solar power development will have to await an increased level of funding.

In addition to managing the funding program, the National Research Council is cooperating with the Housing and Urban Development Association of Canada, the builders' association, on the construction of four energy-conserving experimental houses in Ottawa. One of these will be partially heated with a commercially-available, air-heating solar system and its performance will be described in a future special format report.

Provincial Programs

The province of Ontario is providing the most active support for solar heating of buildings. They were co-sponsors of the Provident Solar House, and are now engaged in the construction of a 30-unit Senior Citizens Home. This building will be monitored and a special format report prepared. Ontario is also supporting work on selective absorber coating; a solar-augmented natural gas heating and cooling system; and a demonstration of a commercial building with mechanical heat recovery and solar heating.

The province of New Brunswick is proceeding with the construction of a commercial building with 650 m^2 of office space and 465 m^2 of warehouse space. A heat-pump augmented solar heating system is planned. The solar system will consist of 117 m^2 of water-heating collectors, and a heat storage unit of 18 m^3 of water. Construction will commence this winter.

Both the provinces of Prince Edward Island and Saskatchewan are planning demonstration buildings featuring energy conservation and utilizing renewable energy sources.

PRIVATE SOLAR HOUSES

At last count, the number of privately funded solar-heated homes in various stages of construction in Canada exceeded fifteen. These use conventional solar-heating systems with piped water or forced-circulation air as heat transfer medium; passive air systems (Trombe); "trickle-on" water systems (Thomason); and the remotely-located air heating solar furnaces. One of these located near Ottawa will be monitored in 1977-78.

COLLECTORS

At this time, there are about 20 solar-heated buildings in Canada using approximately 780 m^2 of collectors. More than half of the collectors used are imported, with much of the remainder being site fabricated. There are about six companies manufacturing solar collectors, and another six to eight companies distributing imported collectors. In the next 12 months, the number of solar-heated buildings should double, and the number of domestically-fabricated solar collectors should show a similar increase.

TABLE I

CANADIAN FEDERALLY-FUNDED SOLAR DEMONSTRATION HOUSES, 1976-77

Location	Living Area (m^2)	Medium	Collector Area (m^2)	Storage Volume (m^3)
(1) Charlottetown, P.E.I.	140	Water	37	13.5 (water)
(2) Halifax, N.S.	136	Air	93	– (rock)
(3) St. John, N.B.	107	Water	56	27 (water)
(4) Fredericton, N.B.	186	Air	18	18 (rock)
(5) Montreal, P. Q.	121	Air	46	10 (rock)
(6) Hudson, P. Q.	250	Water	37	9 (water)
(7) Sherbrooke, P. Q.	110	Air	32	22.5 (rock)
(8) Thunder Bay, Ont.	140	Water	40	– (heat pump assisted)
(9) Winnipeg, Man.	167	Air	–	– (rock)
(10) Regina, Sask.	177	Air	65	– (latent storage)
(11) Calgary, Alta.	106	Water	33	28 (water)
(12) Calgary, Alta.	125	Remote-located, air-heating solar furnace		
(13) Vancouver, B. C.	130	Water	35	4.5 (water)
(14) Vernon, B. C.	130	Water	35	4.5 (water)

SOLAR ENERGY PROJECTS FOR HEATING OF BUILDINGS IN DENMARK

Vagn Korsgaard and Torben V. Esbensen
Thermal Insulation Laboratory
Technical University of Denmark

INTRODUCTION

The main portion of research activities relating to solar energy takes place at the Thermal Insulation Laboratory, Technical University of Denmark.

Since the middle of 1972, preliminary studies have been undertaken regarding the possibilities of using solar energy for heating of buildings under Danish climatic conditions. The studies include measurements on an experimental house heated by solar energy. The research group at the Technical University consists at present of five full-time civil engineers under the direction of Professor V. Korsgaard. The projects are mainly financed by the Danish Council for Scientific and Industrial Research.

In April 1976 the Danish parliament passed an act dealing with energy-political measures. The purpose is to create the basis (infrastructure) for decreasing the country's dependency on imported oil by improved utilization and use of energy and to accelerate the utilization of other energy sources. For this purpose, the government has appointed an Energy Council consisting of 4 scientists and 7 trade and industry members. Professor V. Korsgaard has been appointed vice chairman of the council.

It is expected that a total of 170 mill. d. kr. will be available for increased energy R and D over the next 5 years and that a substantial part will be used for solar heating R and D.

An interim board (chaired by Professor V. Korsgaard) has been formed with the purpose of establishing a Scandinavian section of the International Solar Energy Society.

RESEARCH PROJECTS IN PROGRESS AT THE THERMAL INSULATION LABORATORY

Data for Solar Radiation (H. Lund)

A data collection, the "Reference Year", especially suited for computerized calculations, has been developed within the last two years[1]. The "Reference Year" contains 8760 hourly values of temperature, clouds, solar radiation and other weather data.

The Zero Energy House (M. R. Byberg, T. V. Esbensen, V. Korsgaard)

An experimental house called the Zero Energy House has been in operation since November 1975 on the experimental field at the laboratory [2]. With energy conservation features, such as high-insulated construction (30-40 cm mineral wool insulation), mobile insulation of the windows, and heat recovery in the ventilating system and in the hot water system, the total heat requirement for the house has been reduced to about 1/6 of the heat requirement for a typical one-family house built in Denmark.

The solar heating system is dimensioned to cover the heat requirement for the Zero Energy House during the whole year on the basis of the weather data in the "Reference Year". The solar heating system consists of a 42m^2 flat-plate solar collector, a water storage tank with a capacity of 30 m^3, and a heat distribution system.

Modelling of Solar Heating Systems (K. Kraegpøth, H. Lawaetz)

Different solar heating systems under Danish climatic conditions are calculated by means of computer simulations. In the calculations, the reference year and the heat requirement of typical Danish houses are used. The solar heating system range from a simple domestic hot water system with a one cover flat plate collector to more sophisticated systems with heat storage in eutectic salts and heat pumps. One the basis of the analysis of the systems, an attempt will be made to establish some practical rules for an optimum dimensioning of solar heating systems under the climatic conditions in Denmark.

Concentrating Solar Collector (S. Svendsen)

A solar collector, consisting of a stainless steel reflector and a blackpainted steel pipe in a glass pipe, has been constructed and mounted in a frame following the sun. The results of the test showed that the maximum efficiency of the solar collector was rather poor (25%) due to low specular reflectivity of the reflector plate. As concentrating solar collectors are now commercially available, further investigations will only take place in the form of calculations based on data from the commercial collectors.

Integrated Solar Air Collectors (S. Svendsen)

In this project, flat plate collectors are developed and their efficiency is measured. In the design of the solar collectors, emphasis is put on the cost and the durability. Work is carried out on solar air collectors which can be integrated in the roof construction. Blackpainted metal-plates are used as absorbers behind which the air is circulated. The transparent cover is in one case a conventional greenhouse construction of aluminum and glass.

Performance of an Artificial Sun for Testing (K. Kraegpøth)

For indoor testing and to test the performance of different solar collectors, an artificial sun is under construction in co-operation with the Illuminating Engineering Laboratory.

Projects in the International Energy Agency (J. Lemming)

Sub-project 1: Development of solar heating, cooling, and hot water supplying systems. The objective of sub-project 1 is to establish and organize cooperation between the participating countries in two fields which primarily are related to total systems. The first field covers modelling and simulation of systems in order to calculate the thermal performance. The second field covers measuring and reporting of thermal performance as well as reporting information on durability and cost of systems. These two fields together form the overall objective which is an economical optimization of systems. As a result of the cooperation, each participating country receives the latest results from other scientists in order to avoid duplication of experiments.

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RESEARCH PROJECTS PLANNED FOR THE NEAR FUTURE

Measurement of Solar Radiation (H. Lawaetz)

Measurement of solar radiation will take place at a meteorological site near Copenhagen. The measurements include the direct, diffuse and total irradiance incident on a horizontal surface and the total irradiance on four vertical surfaces with N, S, E, W orientation. The radiation values are measured every ten minutes during the daytime and with the simultaneous observations of other climatic data (e.g. cloud cover), the data will give a very good impression of the solar radiation in Denmark.

Heat Storage in Salt Hydrates (S. Svendsen)

The aim is to develop energy storage which uses sodium sulfate for example, as a storage medium, without having to use small tanks and without separation problems. The new technique consists of adding extra water to the mixture and keeping it soft by stirring. By using large tanks the costs will be reduced considerably.

Assessment of Solar Collectors (S. Svendsen)

In this project, a test stand for measuring thermal performance of solar collectors will be built. Five flat plate collectors using liquid or air as the transfer fluid, with a maximum size of 1.5 x 3.0 m, can be tested in a temperature range from the ambient temperature to 90° C. The project also includes investigation of the long term durability of flat plate solar collectors. This part of the project will be carried out by the Technological Institute.

Low-energy Houses (V. Korsgaard)

Preliminary studies have been initiated regarding a project for construction of 5-6 low-energy houses with different energy conservation equipment. In some of the houses different solar energy systems will be installed.

OTHER SOLAR ENERGY ACTIVITIES IN DENMARK

Temperature Distribution in the Ground

A numerical analysis is underway investigating the possibility of using the ground around a reservoir as an accumulating medium in a solar heating system, where uninsulated water reservoirs are placed in the ground. The project is conducted at the Institute for Numerical Analysis, Technical University of Denmark.

Solar-powered Refrigeration by a Solid-Absorption System

The objective is to develop a solar power refrigeration system to be used in areas where solar radiation is abundant, but other energy sources are either not available or too expensive. The primary application considered is production of block ice; other possible applications are cold storage and milk cooling. The research program is carried out by the Refrigeration Laboratory at the Technical University of Denmark in collaboration with the Institute of Solar Energy, University of Khartoum.

Selective Surfaces

To increase the efficiency of flat-plate solar collectors, selective surfaces are studied at the Laboratory of Technical Optics, Technical University of Denmark.

Information Service

An information service at the Technological Institute in Copenhagen is under preparation in order to provide technological service to individuals.

Solar Heated Swimming Pool

A municipal swimming pool in Greve (south of Copenhagen) is planned to be heated by solar energy. The collector area will be about 500 m^2. Measurement equipment will be installed in the solar energy system.

International Co-operation

The work in the solar heating research projects takes place in close co-operation with research groups in other countries. The laboratory participates in the following international co-operation concerning solar heating of buildings:

CCMS Rational Use of Energy Pilot Study

- Climatic Conditions and Reference Year (chairman: Denmark)

CCMS Solar Energy Pilot Study

- System Reporting Format Committee (chairman: U.S.A.)
- Zero Energy House Experts Group (chairman: Denmark)

EC (European Community)

- Research and Development Program in the Field of Energy-Solar Energy

International Energy Agency – Solar Energy R & D

- Development of Solar Heating, Cooling and Hot Water Supplying Systems (chairman: Denmark)
- Thermal Performance Testing of Solar Collectors (chairman: Germany)
- Development of Components for Solar Heating, Cooling and Hot Water Supplying Systems (chairman: Japan)
- Inference of Insolation Parameters from Existing Meteorological Records (chairman: Sweden).

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SOLAR ENERGY PROJECTS FOR HEATING OF BUILDINGS IN GERMANY

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Kernforschungsanlage Julich*

INTRODUCTION

In response to the oil-price crisis, Germany has initiated a research programme on solar-thermal energy conversion aimed at providing systems for hot water preparation and space heating since the earliest possible energy saving impact is expected from this application. Funding is mainly directed towards industrial firms, whose R & D projects are generally only partially subsidized, in most cases by 50%. Governmental expenditures for solar energy have risen from 1.5 MDM in 1974 to 6 MDM in 1975 and will reach 12 MDM in 1976. The financial ceiling forseen in the programme is 14 MDM per year.

STATUS OF PROJECTS

As of August 1976, a total of 24 solar energy projects were being subsidized by the Federal Government:

- System studies (3)
- Solar-thermal conversion
  - solar houses and demonstration projects (4)
  - complete systems (4)
  - components (7)
- Solar-mechanical conversion for electricity generation and water pumping (3)
- Photovoltaic conversion (2)
- Photochemical conversion (1)

In addition, an unidentified number of small development projects are being carried out by industrial and university laboratories. Furthermore, 30 new R & D proposals are currently being considered. Four of the existing solar-thermal conversion projects have been included in the CCMS Pilot Study: the Phillips house is being studied by the Zero Energy House Group; special format reports will be provided for other house systems and for a large public swimming pool.

It appears that the German private business sector is becoming interested in this field. While the quantity of steel collectors built in this country is not known – due to the large number of producers – the quantity of aluminium roll bond absorbers can be stated: since 1974 10,000 m^2 of absorbers have been sold; the present production rate is 800 m^2 per month. Fifty percent of the production has been and continues to be exported in equal parts to the Netherlands and to Switzerland.

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* Project Management for the Research Program of the Federal Republic of Germany

System Studies

In these studies, the various methods of solar energy conversion are evaluated, not only in regard to the national requirements, but also with a view to possible future exportation of systems and components. One of the studies, for example, compares the various methods of electricity generation for the power range of 100 W to 10 MW.

With respect to solar-thermal energy conversion, the International Institute for System Analysis (IIASA; contract ET 5006 A) is conducting a system study in which the various possibilities and criteria for solar energy conversion in the F.R.G. are being examined. Mid-term and long-term supply of low grade heat, below 100°C, are being evaluated in connection with the more ambitious systems aspects of large scale development potential of solar energy.

The low grade heat applications phase focuses on the identification of the principal solar projects in the F.R.G. (1975/76). Here, the key emphasis is on low temperature regime and on evaluation of the magnitude of energy demand that could be met by accelerated implementation of these options. Among these is large scale assessment of residential, commercial and industrial heating requirements. The importance of institutional aspects (1976-future), including regional and/or federal building constraints, as well as incentives, is recognized, and the principal alternatives will be integrated into the study. The large scale utilization scenarios ranging from "business as usual" to "accelerated implementation program" are evaluated mainly for mid-term (~1980 - 1990) and for long-term (~1990 - 2000) projections. The short-term considerations are viewed primarily as trend indicators. The study is also evaluating the mid-term and long-term large scale system aspects in the areas of district heating, electricity production, hydrogen production, and the related feasibility consideration for various regions of the F.R.G. Solar district heating is being examined for regions where it may become competitive with conventional systems due to favorable insolation values, or where the accessibility to district heating is limited.

Solar Houses *

The Phillips experimental house (contract ET 4052) has been in full operation since June 1975. Precise measurements have been performed (150 measuring points are taken at ½ minute to 1 hour intervals) on its various energy systems in order to compare these with predicted computer results. Since February 1976, the collected solar energy was sufficient to fulfill the total heating requirement, and in March a surplus was obtained. From June 1975 to June 1976, the collected solar energy was 10,350 kWh, giving a year-round collector efficiency of about 45%. The house is equipped with a collector consisting of evacuated glass tubes, now called "Mark 1." Investigations into evacuated selective solar collectors have been continued. Several solar collector types have been analyzed in order to find a simple and effective solution.

The Phillips researchers have also performed a comprehensive statistical analysis on the hourly Hamburg weather data. Based on this data, the energy intensity distributions have been analyzed for different months, years and surfaces. Furthermore, the diffuse, direct and global components have been calculated.

A second study deals with Weather Data Compression. In order to perform a detailed computer analysis of energy systems within a reasonable time limit, a method of data compression has been developed. Good agreement was found when comparing the performance of energy systems under detailed hour-by-hour and compressed weather data.

Since the beginning of 1974, Messerschmidt-Boelkow-Blohm has been engaged in the development of a modular solar house heating system (contract ET 4066). This project is especially intended for application in existing and new one- and two-family houses. In the first development period, all necessary components for the

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*(Only those projects for which special format reports have not been prepared will be mentioned here.)

complete system (especially advanced collector-moduli, regulation, and heat exchangers) were developed and prepared. By mid-1976, more than ten different collector types had been tested, and three prototype designs were selected for series fabrication.

In addition, some technical and economic system analyses have already been made in order to obtain optimum function and minimum costs. Given the available solar radiation intensity and the duration of sunshine in middle European latitudes, 65% of the private energy demand for heating and hot-water preparation can be satisfied by using a 5 m^3 energy storage tank. An essential part of the economic analyses was the determination of all material, manufacturing, and installation costs, as well as detailed requirement analyses to correlate the energy demand, for instance, with house geometry parameters.

In the second development-phase (beginning with the 2nd quarter of 1976), intensive complete-system tests were performed in order to demonstrate the function of the entire system in an existing one-family house. Subsequent quality tests are designed to demonstrate the feasibility of series production. The first full-testing house with an MBB solar-thermal system has been in operation since June 1976. This house is a new candidate for the special reporting format.

Hot Water System

Since January 1975, data have been collected from a typical small hot-water system by the Rheinisch Westfalische Elektrizitatswerke AG, the largest German electric utility company (Contract ET 4025). System data are

collector area: $3 m^2$
$\alpha/\in \sim 1$ (black painted)
double glazing
storage tank: 150 l
daily consumption: 140 l.

The evaluation indicates that even with a simple collector and a small storage tank, 50% of the required energy can be subsituted during the year by solar energy. From May to September, solar energy can satisfy 80% of the energy demand.

The Brown Boveri Company is ready to mass produce water heating systems. One of the purchasers is OKAL, the largest German firm selling prefabricated houses. Fifty houses with solar systems have been ordered.

Collectors

Flat plate collectors with aluminium panels are very well suited for the solar heating and cooling of buildings. They can be produced by economic roll-bond and heat-pipe techniques. The efficiency of such collectors can be considerably increased by using selective surfaces. Savings may result from the elimination of the second glass plate: an 8% higher transmittance, a 30% lower weight, and a simpler supporting structure.

Dornier is attacking the problem of manufacturing high-stability selective surfaces in cooperation with a large aluminum firm. Dornier System has developed a new type of selective coating with outstanding properties (Contract ET 4065). The carpet-like surface structure is formed of tiny closely-packed rods standing upright on the aluminum surface. The separation and diameter of the rods are smaller than the wavelengths of the solar spectrum. The selectivity is rather high, and α values of 95% and $\in$ of 12% can be achieved. The coating shows perfect long-time stability at temperatures up to 200°C, as well as good adhesion strength. The production costs are expected to be about $10 DM/m^2$.

Another competitor in the field of collector production is SCHOTT of Mainz, a well known producer of hard glass (Contract 7202-1-110275). This company supplied the high efficiency collectors for producing hot shower water at the Wiehl public swimming pool. Schott is also producing precise parabolic-cylindrical glass mirrors for concentrating collectors in cooperation with the Swiss Company Liebi LNC.

A different approach has been taken by Kleinwachter (Contract ET 4143 A). The basic element of this special collector is a large, flexible PE-Pipe with a dark bottom and a transparent cover. The material is stabilized against U.V. light and chlorine water. Several layers of flexible plastic foam and reflecting foil provide insulation on the back side of the collector. This basic model operates with very high efficiency (over 80%) for the production of warm water to 40°C. The front face can be supplemented with one or more additional transparent covers. The simplest possibility consists of enveloping the whole collector in a transparent air bubble foil. The aim of this endeavor is an inexpensive collector for swimming pools, greenhouses, houses with flat roofs, and so on.

SUPPORTING ACTIONS

Demonstration Projects

The technical feasibility of solar energy utilization no longer needs to be demonstrated. In view of the vast number of applications for demonstration projects, in the future only the measuring programme will be subsidized.

Data Collection

A country anticipating the future utilization of solar energy must have the means to measure the solar radiation and related parameters in all of its climatic regions and at potential solar energy utilization sites. Furthermore, the design and evaluation of solar energy systems and components require certain essential solar radiation and weather data. A solar data collecting network will be established consisting of a number of small stations set up in meteorologically typical regions. The instrumentation of the stations will be standardized by international cooperation within the International Energy Agency.

Consumer Protection

There are and will continue to be poor quality collectors on the market. Of the ten exhibitors during a recent national solar energy convention, one quoted several 1000 watts per m^2 and claimed to have already sold several systems. There are two reasons why the Government wants to avoid the marketing of poor collectors:

- Heating is a fundamental necessity in our climate. The average citizen who had paid some ten thousand marks for a heating system which does not work will be in a financial difficulties.
- Solar systems with poor energy output will bring disrepute to solar energy utilization and may lead to a serious drawback for the programme.

A quality certificate for collectors, issued by an independent authority (probably a government laboratory) is therefore envisaged. On this certificate, the efficiency of the collector would be stated, thus providing architects and plumbers with basic data for their calculations.

Collector testing is difficult and time-consuming. Scientifically based test procedures are to be worked out by international cooperation. Later on, accelerated indoor tests with a solar simulator will be possible.

FRENCH NATIONAL PROGRAM ON SOLAR HEATING AND COOLING FOR BUILDINGS*

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INTRODUCTION

The first French solar homes were built by Trombe and Michael of the CNRS in 1967. Since 1974 research on solar heating and cooling for buildings has expanded in many organizations, independently at first and then in a more concerted fashion. The Construction Plan, which under the auspices of the Ministry of Equipment furthers and coordinates research and experimentation aimed at raising the quality and lowering the costs of construction, launched a solar heating and cooling for buildings research program in 1974 sponsored by various government laboratories (engineering schools) and private (professional groups) laboratories. Ten solar homes which Electricite de France (EDF) decided to build at Aramon and Le Havre are now completed. CNRS, while continuing its solar experiments, created a review and planning group in 1974 in order to pinpoint the types of research to be encouraged and in 1976 initiated a specific program focusing on the most fundamental aspects of the problem. Informal regional groups have sprung up in cities like Toulouse, Marseilles, Nice, and Montpellier, made up of people interested in advancing solar techniques. Builders (about 15 are presently developing solar energy collectors) and numerous architects are engaged in the development of such techniques.

In 1975 the Commission on New Form of Energy (Ministry of Industry and Research) created the Solar Energy Committee, with J. C. Colli as chairman and R. Chabbal as Vice Chairman. The Committee coordinates the activities of the various research organizations interested in solar energy in all its forms. In addition, in order to cover the cost differential incurred in using solar techniques, the Commission on New Forms of Energy and the Agency for Energy Conservation are jointly subsidizing experimentation and demonstration activities devoted specifically to solar energy for buildings. In 1976 their grants in that field amount to 5 MF. Similar activities are being carried on by the Construction Plan in the more general framework of the Original Thermal Habitat competition. Mention should also be made of the EEC program, started in 1976, which contributes supplementary resources to organizations working on storage and on system analysis.

Glossary of Initials

AEE	Agence pour les economies d'energie – Agency for Energy Conservation
AFEDES	Association francaise pour l'etude et le developpement de l'energie solaire – French Association for Solar Energy Research and Development
CEA	Commissariat a l'energie atomique – Atomic Energy Commission
CETIAT	Centre technique des industries aerauliques – Technical Center for Aeraulic Industries
CNRS	Centre National de la recherche scientifique – National Center for Scientific Research
COMES	Comite de l'energie solaire – Solar Energy Committee

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*Translation by U.S. State Dept.

**National Center for Scientific Research

COSTIC	Comite scientifique et technique des industries du chauffage, de la climatisation et du conditiononnement – Scientific and Technical Committee of the Heating and Air Conditioning Industries
CSTB	Centre scientifique et technique du batiment – Scientific and Technical Center for the Construction Industry
DEN	Delegation aux energies nouveiles – Commission on New Forms of Energy
EDF	Electricite de France – French National Electric Company
ENSAIS	Ecole normale superieure des arts et industries de Strasbourg – Advanced School of Crafts and Industries of Strasbourg
ESIM	Ecole superieure d'ingenieurs de Marseille – Marseilles Institute of Engineering
G2H	Groupement pour l'heliotechnique et l'habitat – Heliotechnics and Housing Group
PC	Plan-Construction – Construction Plan

BASIC AND APPLIED RESEARCH CONDUCTED BY CNRS

Solar Housing Program

The general aim of this program is to support basic research necessary for the practical development of solar heating and cooling systems for buildings.

Topic 1: Bioclimatic Study of the Notion of Comfort (Joint undertaking of CNRS and Construction Plan)

Aim: Defining comfortable temperature conditions for different types of activity, including study of interaction between the perception of comfortable temperatures and the perception of other comfort factors.

Activities in 1976:

- Measuring heat and relative humidity as comfort factors during sleep
- Evaluation of thermal comfort perceived in actual situations (CNRS Center for Bioclimatic Studies, Strasbourg)
- Study of heat regulation responses linked to internal temperature as a function of clothing and temperature (Physiology Laboratory, Lyons)

Topic 2: System Analysis for Buildings

Aim: Modeling, analog simulation, and experimentation with sub-systems (surfaces) or more complex systems.

Activities in 1976:

- Transfer functions applicable to particular points on a building shell (INSA, Lyons)
- System analysis of collector surfaces (Study and Research Center, Toulouse)
- Dynamic model of a collection/storage system with random input and output (University of Orsay)

Topic 3: Studies of Components (Collectors, Storage, Cooling)

Aim: Study of radiative and convective exchanges at a collector surface. Study of refrigeration and dehumidifying systems, especially with respect to optimization of absorption cycles.

Activities in 1976:

- Simultaneous convection and radiation in flat plate collectors as a function of surface states, temperature gradients, optical absorption properties, collector geometry, and other parameters (CNAM Paris, University of Paris VI, Marseilles Solar Physics Laboratory)
- Thermally anisotropic composite structures (LEAT, Poitiers)
- Kinetics of stored heat restitution in solids
- Study of isothermal surfaces with latent heat storage (Nice Observatory)
- Utilization of solid absorbents (zeolities) for solar cooling (University of Orsay)

Solar Heating and Cooling for Buildings Projects (Solar Energy Laboratory, Odeillo)

Construction of and experimentation with dwellings having collector surfaces facing south and air circulation (Trombe-Michel system):

Phase 1: See Report on experiments (distributed at CCMS Conference, Copenhagen, 1976).

Phase 2: Apartment buildings completed in 1975, undergoing tests.

SCIENTIFIC RESEARCH PROGRAMS IN SOLAR ENERGY AND HOUSING CONDUCTED BY THE CONSTRUCTION PLAN (MINISTRY OF EQUIPMENT) AND OTHER ORGANIZATIONS

The general aim of the programs is to further scientific, technical and architectural research leading to better utilization of solar techniques in buildings in temperate climates.

The preliminary phase of the Construction Plan covered 1974 - 1975. This research was first designed to furnish scientific, technical, and economic data on the collection, storage, and controlled use of solar heat to designers, technicians, and contractors:

- ESIM: Water collector tests; storage optimization
- ENSAIS: Controlled environment test cell for the study of the regulation, collection, and use of solar heat in air systems; architectural integration tests on air systems
- CSTB: Analog simulation of systems
- Groupement Aerien H: Classification of architectural types and architectural design procedures for better solar energy utilization
- COSTIC: Processing of National Weather Service data for preparation of a heliothermal atlas.

The programs underway in 1976 are described below.

Testing Stations

Natural climate testing stations have been built with the aid of the Construction Plan at two engineering schools: ESIM and ENSAIS. Artificial climate testing stations have been built by EDF (Renardieres Center) and CEA (for collectors). CETIAT (Lyons) is considering the construction of such a station.

Collectors

- High temperature collectors, selective layer studies: CEA (Grenoble), CNRS (Marseilles)
- Run-off collectors (Liebart)

AFEDES has set up a working group on test standardization.

Storage (Under the framework of the Construction Plan)

- Water storage is being studied at ESIM (modeling of temperature stratification).
- Pebble-bed storage is being studied at COSTIC.
- Eutectic storage is being studied at ESIM and CSTB.
- An exploratory study on shallow underground or geothermal water storage has been assigned by the Construction Plan to COSTIC.

System Analysis, Simulation

ESIM, ENSAIS, EDF, and COSTIC natural or artificial climate testing stations (see above) are used for real-time studies of components and complete systems in controlled thermal environments. Construction Plan projects for 1976 involve tests of water collectors and various storage systems and the improvement of installation analysis methods (ESIM) and air system regulation (ENSAIS).

Those experimental analyses are complemented by simulation studies of various types:

Analog simulation: CSTB's analog simulation program supported by the Construction Plan has two phases:

- 1975-76: Solar energy input in relation to heat loss from buildings; possibilities of recovering solar input in current construction.
- 1976-77: Study of specific storage systems (water, pebble, eutectic).

Computer simulation: Simplified calculations by which complete systems (COSTIC, EDF, Bertin) can be tested economically are very useful. For example, EDF has developed a system of charts which makes possible the fast, simple calculations required by designers: the additional hourly consumption of a given solar dwelling is estimated within 10 percent.

Architectural Research

In the framework of the Construction Plan, Groupement Aerien H is doing a study of traditional architectures and trying to articulate design methods suitable for modern buildings utilizing solar energy.

An international inventory of solar architectural approaches is being prepared at the Ministry of Cultural Affairs. At the same time, two inquiries have been started with an eye to possible modification of existing dwellings, the first on users' intentions and the second on the technical possibilities of such modification.

EXPERIMENTS AND DEMONSTRATIONS IN SOLAR HEATING AND COOLING IN BUILDINGS

GOVERNMENT FINANCING PLACE DESIGNER	PROGRAM SYSTEM	EXPECTED ENERGY SAVINGS DATE OF INAUGURATION COST DIFFERENTIAL
CNRS Odeillo (second phase) Michel, Trombe	Collective unit for 3 separate houses Concrete wall, hot-air flue, electric auxiliary	50% January 1975
EDF Le Havre (s. -Mar.) Michel and Alex Chouleur	5 separate houses, 108 m^2 46 m^2 water collector, 4 m^3 static convectors, electric auxiliary	30-40% 1976 F30,000/dwelling
EDF Aramon (Gard)	Same as above	Same as above
P-C Blagnac (H. -C.) Lieb art, Pereira	5 separate low income houses, 100 m^2 30 m^2 run-off water collectors, 3 m^3 reservoir, hot air, gas auxiliary	65% December 1976
P-C Rousset (B. -du-R.) ESIM, Grimabet	16-unit low-income building Floor heating, electric auxiliary	60% 1977 F32,600/housing unit
P-C Marseilles region SGTE, SOFEE, Mosser	Two 20-unit buildings Water collectors, 1.5 m^3 stratification reservoir, conventional hot water supply	65% 1977 F6,000/housing unit
DEN-AEE Alès (Gard) Elf, COSTIC, Sage	Ecole des Mines student center (Fifteen 20-room buildings) 1215 m^2 water collectors, 15x3 m^3 water storage, distribution by radiators, gas auxiliary	50% (100 OET) (1) 1976, (2) 1977 F1.5 million
DEN-AEE Nyons (Drôme) Lainville, Bord	61 housing units in 4 buildings (La Palmeraie development) 574 m^2 water collector	90 OET 1977 F660,000
DEN-AEE Carbonne (H. -G.) G2H	12-classroom nursery school 260 m^2 collectors	15 OET 1976 F300,000
DEN-AEE Vinsobres (Drôme)	School 150 m^2 collectors	12 OET 1976 F120,000

EXPERIMENTS AND DEMONSTRATIONS IN SOLAR HEATING AND COOLING IN BUILDINGS

(Continued)

GOVERNMENT FINANCING PLACE DESIGNER	PROGRAM SYSTEM	EXPECTED ENERGY SAVINGS DATE OF INAUGURATION COST DIFFERENTIAL
DEN-AEE Château-Arnoux (A. -de-H. -P.)	Swimming pool (2 enclosed pools) 400 m^2 collectors	140 OET 1976 F460,000
DEN-AEE Ajaccio (Corse-S.)	60-crib day care center 117 m^2 collectors	16 OET 1977 F100,000
DEN-AEE Hyères (Var)	Agricultural high school	50 OET 1976
	2400 m^2 glass-house collectors, 600 m^2 collectors	F280,000
DEN-AEE Saint-Peray (Ardeche)	1000 m^2 sports arena of the gymnasium Concrete-wall collector (Trombe-Michel System)	58 OET 1977 F400,000
DEN-AEE Béziers (Hérault)	Vocational training center (5000 m^2) Concrete-wall collector (Trombe-Michel System)	127 OET 1977 F1 million
DEN-AEE Salon (b. -du-R.)	Internal revenue building 340 m^2 collectors	40 OET 1977 F600,000

Nineteen other projects, more recent or less ambitious, or limited to water-heating, are also in progress.

CONCLUSIONS

At the current stage of an endeavor that is well under way, French research on solar heating and cooling for buildings is active and well-coordinated. But the development phase has barely begun (except where flat plate collectors are concerned; they are being manufactured by about 10 companies, the largest of which has a capacity of 10,000 square meters per year). Ongoing experiments and demonstrations are a first step in measuring the potential impact of solar heating and cooling techniques, selecting the most effective approaches out of the current profusion of ideas, and, eventually, developing a real industry. Simultaneous scientific and architectural research is indispensable. While it is true that international action can be useful, let us note in closing that it is very important to develop local and regional competence and interest in solar heating and cooling for buildings.

LE PROGRAMME NATIONAL FRANCAIS SUR L'HABITAT SOLAIRE

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INTRODUCTION

Les premières "maisons solaires" françaises ont été construites par TROMBE et MICHEL au C.N.R.S. en 1967. Depuis 1974, la recherche sur l'habitat solaire s'est développée dans de nombreux organismes, d'abord indépendamment puis de façon plus concertée. Le Plan-Construction, qui, au sein du Ministère de l'Equipement, encourage et coordonne la recherche et l'expérimentation visant à accroitre la qualité et à abaisser le coût de la construction, a lancé en 1974 un programme de recherche sur le thème de l'habitat solaire, s'appuyant sur différents laboratoires public (écoles d'ingénieurs) ou privés (groupements professionnels). L'E.D.F. a décidé la construction d'une dizaine de maisons solaires à Aramon et au Havre, qui est maintenant achevée. Le C.N.R.S., tout en continuant l'expérimentation d'habitat solaire, a réuni en 1974 un groupe de réflexion et de prospective pour préciser les thèmes de recherche à encourager, puis a lancé en 1976 une action thématique programmée sur les aspects les plus fondamentaux du problème. Des groupements régionaux informels se sont constitués, notamment à Toulouse (G2H), à Marseille, à Nice et à Montpellier, entre personnes désireuses de faire progresser les techniques de l'habitat solaire. Des constructeurs (actuellement une quinzaine pour les capteurs solaires) et de nombreux architectes contribuent à développer ces techniques.

En 1975 a été formé, au sein de la Délégration aux Energies Nouvelles (Ministère de l'Industrie et de la Recherche), le Comité de l'Energie Solaire, dont le Président est J. C. COLLI et le Vice-Président R. CHABBAL. Ce Comité coordonne l'action des différents organismes de recherche intéressés à l'énergie solaire sous toutes ses formes. De plus, dans le domaine particulier de l'habitat solaire, la Délégation aux Energies Nouvelles et l'Agence pour les Economies d'Energie accordent conjointement des subventions aux opérations de'expérimentation et de démonstration, de façon à couvrir le surcoût occasionné par l'emploi des techniques "solaires". En 1976, le montant total de ces subventions est de 5 000 000 F. D'autres actions similaires sont menées par le Plan-Construction dans le cadre plus général du concours HOT (Habitat original par la thermique). Mentionnons également en 1976 le début du programme de la Communauté Economique Européenne, qui apporte aux organismes travaillant sur le stockage et sur l'analyse de systèmes des moyens complémentaires.

LEXIQUE DES SIGLES

AEE	Agence pour les économies d'énergie
AFEDES	Association française pour l'étude et le développement de l'énergie solaire
CEA	Commissariat à l'énergie atomique
CETIAT	Centre technique des industries aérauliques
CNRS	Centre national de la recherche scientifique
COMES	Comité de l'énergie solaire
COSTIC	Comité scientifique et technique des industries du chauffage, de la climatisation et du conditionnement

CSTB	Centre scientifique et technique du bâtiment
DEN	Délégation aux énergies nouvelles
EDF	Electricité de France
ENSAIS	Ecole normale supérieure des arts et industries de Strasbourg
ESIM	Ecole supérieure d'ingénieurs de Marseille
G2H	Groupement pour l'héliotechnique et l'habitat
PC	Plan-Construction

I – RECHERCHES FONDAMENTALES ET APPLIQUEES MENEES PAR LE C.N.R.S.

I. – 1. Action Thématique Programmée "Habitat Solaire"

Objectif général (1976): Soutenir les recherches fondamentales nécessaires au développement pratique de systèmes d'habitat solaire.

THEME 1: Etude bioclimatique de la notion de confort (action commune du C.N.R.S. et du Plan-Construction)

Objectif: Délimitation des conditions de confort thermique en régimes variés, en fonction des activités. Interatctions entre la perception du confort thermique et celle d'autres facteurs du confort global.

Actions 1976:

- Indicateurs de confort thermo-hygrométrique au cours du sommeil
- Evaluation du confort thermique déclaré en situation réelle (Centre d'Etudes Bioclimatiques du C.N.R.S., Strasbourg)
- Etude des réponses thermorégulatrices liées à la température interne en fonction de l'habillement et de la température (laboratoire de Physiologie, Lyon).

THEME 2: Analyse-système de l'habitat

Objectif: Modélisation, simulation analogique et expérimentation de sous-systèmes (parois) ou de systèmes plus complexes.

Actions 1976:

- Fonctions de transfert relatives aux points singuliers de l'enveloppe d'un local (INSA, Lyon).
- Analyse-système de parois collectrices (Centre d'Etudes et Recherches, Toulouse)
- Modèle dynamique d'un système de captation-stockage avec entrées et sorties aléatoires (Université d'Orsay)

THEME 3: Etudes de composants (capteurs, stockage, réfrigération)

Objectif: Etude des échanges radiatifs et convectifs à la surface d'un capteur. Etudes dynamiques de systèmes de stockage. Etude de systèmes de réfrigération et déshumidification, notamment optimisation de cycles à absorption.

Actions 1976:

- Couplage convection-rayonnement dans les capteurs plans en fonction des états de surface, des gradients de témperature, des propriétés d'absorption optique, de la géométrie du capteur et d'autres paramètres (CNAM Paris, Université de Paris VI, Laboratoire d'héliophysique Marseille).

- Structures composites thermiquement anisotropes (LEAT, Poitiers)
- Cinétique de restitution de la chaleur stockée dans des solides (id.)
- Etude de parois isothermes a stockage par chaleur latente (Observatoire de Nice)
- Utilisation d'adsorbants solides (zéolites) pour la réfrigération solaire (Université d'Orsay).

I. – 2. Action spécifique sur l'Habitat Solaire (Laboratoire d'Energie Solaire, Odeillo)

Construction et expérimentation d'habitations à collecteur mural en façade sud et circulation d'air (système Trombe-Michel):

- Phase 1: voir compte-rendu d'essais (Conférence CDSM Copenhague 1976).
- Phase 2: maisons collectives terminées en 1975, en cours d'essai.

II – PROGRAMMATION DES RECHERCHES SCIENTIFIQUES SUR ENERGIE SOLAIRE ET HABITAT MENEES PAR LE PLAN CONSTRUCTION (Ministère de l'Equipement) ET D'AUTRES ORGANISMES

Objectif général: Développement des recherches scientifiques, techniques et architecturales permettant à terme une meilleure utilisation des apports solaires dans l'habitat en climat tempéré.

Phase préliminaire du Plan-Construction (1974-75) :

Ces recherches visaient initialement à fournir à l'ensemble des concepteurs, techniciens et maitres d'oeuvre des données scientifiques, techniques et économiques sur la captation, l'accumulation et la restitution régulée de la chaleur solaire:

- ESIM: Tests de capteurs à eau. Optimisation du stockage.
- ENSAIS: Cellule d'ambiance contrôlée pour l'étude de la régulation, de la captation et de la restitution des calories dans les systèmes aerauliques. Essais d'intégration architecturale des systèmes à air.
- CSTB: Simulation analogique de systèmes.
- Groupement Aérien H: Typologie des architectures et processus de conception architecturale pour une meilleure utilisation de l'énergie solaire.
- COSTIC: Dépouillement des données de la Météorologie Nationale, en vue d'un atlas héliothermique.

Programme en cours (1976)

II – 1. Stations D'Essai

Des *stations d'essai en climat naturel* ont été construites avec l'aide du Plan-Construction dans deux écoles d'ingénieurs: ESIM et ENSAIS.
Des *stations d'essai en climat artificiel* ont été construites, d'une part par l'E.D.F. (Centre des Renardières) d'autre part par le CEA (pour les capteurs).

Le CETIAT (Lyon) envisage de construire une telle station.

II – 2. Capteurs

- Capteurs à haute température, etudes de couches sélectives: CEA (Grenoble), CNRS (Marseille).
- Capteurs à ruissellement (M. LIEBART)

L'AFEDES a créé un groupe de travail sur la normalisation des essais.

II – 3. Stockage

Dans le cadre du Plan-Construction:

Le *stockage à eau* est étudié à l'ESIM (modelisation de la stratification des températures).

Le *stockage en lit de cailloux* est étudié au COSTIC.

Le *stockage en eutectiques* est étudié à l'ESIM et au CSTB.

Une étude exploratoire sur le *stockage en nappes phréatiques ou géothermiques* peu profondes a été confiée par le Plan Construction au COSTIC.

II – 4. Analyse De Systeme, Simulation

Les *stations d'essai* en climat naturel ou artificiel (cf. supra): ESIM, ENSAIS, EDF, COSTIC sont utilisées pour étudier en temps réel dans des enceintes thermiques contrôlées des composants et des systèmes complets. Les travaux du Plan-Construction en 1976 portent sur:

- tests de capteurs à eau, divers systèmes de stockage, mise au point de méthodes de calcul d'installations (ESIM)
- régulation des systèmes à air (ENSAIS).

Ces analyses expérimentales sont complétées par des études de simulation de divers types:

Simulation analogique:

Le programme de simulation analogique du CSTB appuyé par le Plan-Construction comprend deux phases:

- 1975 - 76: concomittances entre les apports solaires et les déperditions des bâtiments; possibilités de récupération des apports solaires en construction courante
- 1976 - 77: étude de systèmes de stockage spécifiques (eau, cailloux, eutectiques)

Simulation sur ordinateur:

Un intérêt particulier s'attache à développer des *calculs simplifiés* permettant de tester économiquement des systèmes complets (COSTIC, EDF, Bertin). Par exemple, l'EDF a mis au point un réseau d'abaques permettant les calculs simples et rapides que demandent les projeteurs: on évalue à 10% près la consommation d'appoint d'une maison solaire déterminée en une heure environ.

II – 5. Recherches Architecturales

Dans le cadre du Plan Construction, le Groupement Aérien - H mène une études des architectures traditionnelles et tente de définir des méthodes de conception adaptées à un habitat moderne incluant l'utilisation de l'énergie solaire.

Un recensement international des solutions architecturales solaires est en cours au Ministère des Affaires Culturelles. En parallèle, deux enquêtes ont été lancées pour préparer des modifications éventuelles du parc de logements existants:

- enquête sur les intentions des usagers
- enquête sur les possibilités techniques de modification du parc.

III – EXPERIMENTATION D'HABITAT SOLAIRE ET OPERATIONS DE DEMONSTRATION

Financement public Lieu Concepteur	Programme Systeme	Economie attendue Mise en service Surcout
CNRS Odeillo (2 eme phase) Trombe, Michel	Collectif de 3 maisons individuelles Mur beton, gaine a air chaud, appoint electrique	50% janvier 1975
EDF Le Havre (S. -Mar.) Chouleur, Michel, Alex.	5 maisons individuelles 108 m^2 Capteur eau 46 m^2, ballon 4 m^3 convecteurs statiques, appoint electrique	30 a 40% 1976 30 000 F/logement
EDF ARAMON (Gard) P.C. BLAGNAC (H. Gar.) Liebart, Pereira	meme programme 5 maisons individuelles 100 m^2 HLM capteurs eau ruisselants 30 m^2, ballon 3 m^3, air chaud, appoint gaz	id. 65% decembre 1976
P.C. ROUSSET (B. du Rh.) ESIM, Grimabet	Batiment collectif 16 logements HLM chauffage plancher, appoint electrique	60% 1977 32 600 F/logement
P.C. Region Marseille SGTE, SOFEE, Mosser	2 batiments collectifs de 20 logements Capteurs eau, ballon 1,5 m^3 a stratification, distribution eau chaude classique	65% 1977 6 000 F/logement
DEN-AEE Ales (Gard) Elf, COSTIC, Sage	Foyer etudiants Ecole des Mines (15 batiments de 20 chambres) Capteurs eau 1215 m^2, stockage eau 15x3 m^3, distribution radiateurs, appoint gaz	50%(100 TEP) 1) 1976 2) 1977 1 500 000 F
DEN-AEE NYONS (Drome) Lainville, Bord	61 logements en 4 batiments (resid. la Palmeraie) Capteur eau (574 m^2)	90 TEP 1977 660 000 F

III – EXPERIMENTATION D'HABITAT SOLAIRE ET OPERATIONS DE DEMONSTRATION

(Continued)

Financement public Lieu Concepteur	Programme Systeme	Economie attendue Mise en service Surcout
DEN-AEE CARBONNE (H. Gar.) G2H	Ecole maternelle de 12 classes 260 m^2 capteurs	15 TEP 1976 300 000 F
DEN-AEE VINSOBRES (Drome)	Groupe scolaire 150 m^2 capteurs	12 TEP 1976 120 000 F
DEN-AEE CHAT. ARNOUX (Alp. H. Provence)	Piscine (2 bassins couverts) 400 m^2 capteurs	140 TEP 1976 460 000 F
DEN-AEE AJACCIO (Corse Sud)	Creche (60 berceaux) 117 m^2 capteurs	16 TEP 1977 100 000 F
DEN-AEE HYERES (Var)	Lycee agricole: serres de 2400 m^2 600 m^2 capteurs	50 TEP 1976 280 000 F
DEN-AEE ST-PERAY (Ardeche)	Salle de sports de 1000 m^2 du gymnase Capteur = mur beton (syst. Trombe-Michel)	58 TEP 1977 400 000 F
DEN-AEE BEZIERS (Herault)	Centre de formation professionnelle (5000 m^2) Capteur = mur beton (syst. Trombe-Michel)	127 TEP 1977 1000 000 F
DEN-AEE SALON (B. du Rh.)	Hotel des impots 340 m^2 capteurs	40 TEP 1977 600 000 F

19 autres opérations, soit plus récentes, soit de moindre importance (ou limitées a la production d'eau chaude) sont également en cours

CONCLUSIONS

Au stade actuel d'un effort qui est déjà important, la recherche francaise sur l'habitat solaire est menée activement et bien coordonnée. Mais l'étape du développement est à peine abordée (sauf pour les capteurs plans, qui sont fabriqués par une dizaine d'entreprises, dont la plus importante a une capacité de 10 000 m^2/an). Les opérations en cours d'expérimentation et de démonstration sont un permier pas pour mesurer l'impact possible des techniques solaires, sélectionner dans le foisonnement d'idées actuellement constaté les voies les plus efficaces et préparer éventuellement une industrialisation sérieuse. La poursuite de recherches scientifiques et architecturales est en même temps indispensable. S'il est vrai que des actions à caractère international peuvent avoir une utilité, notons pour conclure qu'il est très important de développer au niveau local et régional des compétences et de l'intérêt pour l'habitat solaire.

SOLAR ENERGY ACTIVITIES IN GREECE

A.A. Deliyannis and E.A. Deliyannis
Nuclear Research Center "Democritos"

There is currently no official national program in Greece for research in solar heating and cooling of buildings. The Government is encouraging private initiative in developing processes and applications. Highlights of the activities in Greece are summarized as follows:

DOMESTIC HOT WATER UNITS

About 15 years ago, an attempt was made to introduce solar water heaters in the country. It was not successful, because electricity was very cheap at that time. The greatest majority of houses and apartments have electric water heaters.

The energy crisis again raised interest in solar water heating and presently a number of manufacturers are marketing solar water heaters for individual families.

HOT WATER FOR HOTELS

At the present time, three hotels are producing the required hot water by solar heat:

Marathon Beach Hotel: Collectors titled at 45° with $70m^2$ heat absorbing area in the first stage. $40m^2$ additional collecting area are to be installed. Capacity 320 beds.
Valery Hotel in Crete: 18 collectors installed with $25m^2$ total area. Hotel capacity 76 beds.
Para-Mera Hotel in Mykonos: 40 collectors totaling $56m^2$ installed. Hotel capacity 150 beds.

All three hotel installations were erected in 1976.

COLLECTOR DEVELOPMENT

Research is being performed at the University of Patras to test a novel configuration of flat plate collector design with the aim of minimizing heat losses to the environment.

Another type of reflecting horizontal solar collector was developed at the Nuclear Research Center "Democritos". The collector is composed of a number of parallel small pipes with fins. Whereas the collector is placed horizontally, with a slight inclination for drainage purposes, a tilt is given to the fins similar to that of a conventional collector at the same latitude. A reflecting surface is adapted in the space between two consecutive finned pipes, so that the collector consists of alternate stripes of tilted absorbing fins and reflecting surfaces. The prototype collectors tested both had a single glass pane.

The total heat absorbing surface of the prototype collector has an area of $1.75m^2$ and the total horizontal area occupied by the collector as a whole is about $3.30m^2$. According to the sun's position a reflection takes place, which increases the amount of incident solar radiation on the absorbing black surface. Significantly higher temperatures are obtained in the circulating fluids.

SOLAR HEATED HOUSE

A private house under construction with $570m^2$ area is designed to be heated by hot water from solar collectors. Cooper tubes are inbedded in the floor as heat carriers. Total collector area is $80m^2$. It is expected that 70% of the heating and domestic hot water requirements will be covered by solar heat.

SOLAR HEATED OFFICE BUILDING

Part of the new administration building of the Nuclear Research Center "Democritos" will be solar heated, starting 1977. The first phase provides for heating of 12 rooms with an area of $450m^2$. Existing single pane windows are reinforced by a second pane to increase efficiency.

Horizontal flat plate collectors are used, developed at the Center. About 100 collectors with a total absorbing area of about $150m^2$ will be erected during Phase 1. Collectors are connected in batteries of three in series. An extensive instrumentation will collect data to be used in future projects.

In Phase 2 the whole roof of the Administration Building will be provided with solar collectors, in order to extend the solar heated area. The present heating system has an oil heated water distribution system and fan coils as heating elements. The system has several individual water distribution loops. As solar heat is available from additional collectors, further loops will be switched over from oil to solar heating.

PROTOTYPE SOLAR COMMUNITY

The Greek Government has signed an agreement with ERDA for a study aimed at the construction of a prototype solar community in Greece.

SOLAR ENERGY RESEARCH AND DEVELOPMENT IN IRAN

S. R. Larijani
Ministry of Energy

INTRODUCTION

We live in a century that, among other things, will come to be known as the century of oil, Iran blessed with rich oil reserves, is rapidly acquiring the capital needed to develop not only a modern industrial society, but also the alternate energy sources to sustain that society beyond the year 2000.

The transition to a post – oil economy may be temporarily eased by the exploitation of other fossil fuels: coal in the U.S.A. and natural gas in Iran, for example. However, the need for alternate energy sources is already with us as Iran clearly recognizes in its policy of oil pricing.

The principal long-range energy sources are nuclear energy and solar energy. Solar energy is nonpolluting and widely distributed; nuclear energy is polluting and centralized. Both nuclear energy and solar energy are capital-intensive, which means that their development will be restricted to those countries having large capital resources. Few countries can hope to develop both.

With a relatively low average of annual rain fall of about 300 mm., Iran enjoys good year-round insolation. The yearly average of solar energy received is estimated to be around 5KWhr/d.m^2. Therefore, Iran's best strategy would be to emphasize domestic support of solar energy research and development.

The principal energy-consuming sectors of a modern economy are:

1. The heating and cooling of domestic and commercial buildings.
2. Transport.
3. Process steam for industry, and
4. Electric-Power generation.

Development of solar heating and cooling of buildings appears practical and it is especially appropriate for Iran. Although our research centers in Iran are in their infancy, nevertheless their achievements in the field of solar energy are quite promising, and it seems pertinent particularly from the point of view of this meeting, which concentrates on solar heating and cooling in buildings, to give you a brief description of Iran's activities in the field of thermal applications of solar energy.

The solar energy research and development activities in Iran are mainly carried out under the direct supervision of the Council for Solar Energy Research and Development, at following centers:

1. Material and Energy Research Center (MERC)
2. Solar Energy Research Center of Pahlavi University.

SOLAR ENERGY RESEARCH AT MERC

Four solar energy collectors have been built and tested at MERC over the summer, as a first effort in a research programme on solar energy utilization. In this programme, several applications of solar energy will be considered including water heating, space heating and air conditioning.

Three types of flat plate collectors were designed and built. Each collector consists of a black metal plate with appropriately designed water passages, housed in an insulated casing and covered with glass. Solar radiation is absorbed by the plate and converted into heat which is transferred to the water. The insulation and glass cover reduce the heat loss from the collector to the environment by convection and conduction.

Flat plate collectors are relatively inexpensive to build, do not require tracking of the sun, and can be placed on the roof or incorporated in it in an architecturally attractive manner. They have the additional advantage that they collect both direct and diffuse solar radiation and can thus supply heat even in cloudy weather.

The three collectors built at MERC were evaluated in a specially designed test facility which allowed testing under steady state conditions. Conversion efficiencies of up to 90% and water temperatures up to 80°C were obtained under various operating conditions. These temperatures are quite sufficient for most domestic needs. An economic study is presently underway to determine the cost of producing flat plate collectors in Iran. The experience obtained with these collectors will be useful in the next stage of the programme which will involve the design and construction of a system supplying hot water to the MERC building.

One important limitation of flat plate collectors is that they normally cannot supply heat at temperatures exceeding 100°C. While these temperatures are adequate for water and space heating, higher temperatures are required for the efficient operation of air conditioning systems. In anticipation of constructing solar air conditioning at MERC, a concentrating collector was also built and tested which could easily supply water under pressure or steam at 150°C.

The collector consists of a reflector in the shape of a semi-cyclinder of parabolic section made from chrome plated steel supported on a wooden frame. An absorber in the form of a blackened coil inside an evaculated glass tube is placed along the line focus of the reflector, and this line is positioned in the east-west direction so that the solar motion during the day does not need to be tracked. Changes in solar declination are accommodated by changing the tilt angle of the reflector periodically.

This first prototype is capable of reaching 150°C. Further improvements will be achieved when the parabolic focusing of the reflector is improved by using more accurate construction techniques and when heat loss from the absorber is reduced by using selective coatings which have high absorption at the solar wavelengths but low absorption, and hence low emissivity, at the longer wavelengths appropriate to radiative heat loss from the coil at 150°C. This possibility is being examined further in the Materials Engineering Laboratory at MERC.

Thus we will soon be able to demonstrate the way in which solar energy can be used by domestic consumers in Iran by converting the water heating system of MERC to solar power and adding a solar air conditioning system to it. We are including economic considerations prominently in our designs and hope that Iranian industry will be able to use these in order to supply the potentially large internal market for solar systems of this kind which exists in this country.

The future research program of (MERC) consists of the following projects:

1. Heating and cooling of buildings.
2. Industrial process team.
3. Electric – power generation
4. Total energy system for a typical village.
5. Hydrogen production.
6. The CNRS/MERC project:
   The CNRS/MERC project has these objectives: (1) Prototype design and systems analysis for solar conversion particularly thermodynamic conversion systems for both a village of 50-200 people and for a new urban community and (2) a paper study of the possibilities for solar energy utilization in Iran particularly for thermodynamic electricity generation in the cities.

SOLAR ENERGY RESEARCH AT PAHLAVI UNIVERSITY, SHIRAZ

The solar energy research in Shiraz started in 1969 and has been limited to thermal applications, such as:

- Solar house heating
- Water desalination
- Solar dehydration
- Solar cooking
- Solar sterilization of medical instrument
- Solar power production

For the future activities of this centre, it should be added that all research activities will be concentrated on the two following projects:

- Design and construction of 1 MW solar-thermal power plant
- Design and construction of 10 MW solar-thermal power plant.

SOLAR HEATING AND COOLING IN BUILDINGS
REPORT FROM ISRAEL

Harry Tabor
The Scientific Research Foundation

INTRODUCTION

The activities for this last year are substantially the same as those reported in July 1975. The same companies and institutions are involved, except that one new company has appeared offering a water heater combining collector and storage tank into a single unit, and another company has introduced a finned collector.

Recapitulating on the earlier report, the current activities fall into eight groups:

(1) Work related to solar collector development.
(2) Systems and simulation.
(3) Auxiliaries.
(4) Architecture and climatology.
(5) Testing and standards.
(6) Miscellaneous.
(7) Solar heated and cooled houses.
(8) Solar ponds.

COLLECTOR DEVELOPMENT

Flat Plate Collectors

Until the present time, most of the commercially available collectors have been of the tube and plate type. However, in the last year, several new collectors have appeared on the market. These include double wall (plate-coil) types (which are, in general, only suitable in closed cycle systems as the cavity cannot be adequately protected against corrosion) and a collector in the form of a tube with closed-space fins (as used in coil fan units). Some work has started on solar collectors as an integral constructional element of a building.

Concentrating Collectors

Work is continuing on the spherical mirror type collector with tracking radial absorber.

SYSTEMS AND SIMULATION

As indicated in last year's report, almost all solar hot water installations were for individual apartments, and studies are in progress on large installations and the problems of control related to them. In the current year several large installations have been completed, the largest being hot water supply for a hotel, using 150 m^2 of flat plate collectors, 10,000 litres storage capacity and gas-fired back-up.

AUXILIARIES

A differential thermostat has been developed and marketed by one company; another company is developing a small circulating pump intended for small installations.

ARCHITECTURE AND CLIMATOLOGY

Studies continue on such subjects as orientation, special windows, and radiation cooling. This work is mostly concentrated in the Haifa Institute of Technology and the Ben Gurion University of the Negev.

TESTING AND STANDARDS

Several institutions conduct testing of collectors, but the establishment of a agreed procedure – to replace the outdated standards prepared many years ago – has not yet been completed. There is a standard of construction that is valid and the Standards Institution of Israel has issued its seal of approval to one manufacturer at least.

MISCELLANEOUS

Studies are being carried out on different cooling systems. At least one institution is studying solar air conditioning with desiccants. Some work is proceeding on selective surfaces.

SOLAR HEATED AND COOLED HOUSES

A private residence in Tiberias has been designed by a consulting engineering company to be heated and cooled with flat plate collectors used as air heaters (for winter operation) and as refrigerant fluid heaters for summer. To date, only the heating phase has been completed.

General Comment: Because the heating season in Israel is short, it is difficult to justify – on economic grounds – a solar heating system for buildings unless summer cooling is included. As is well known, this means more sophisticated collectors and systems engineering. The Tadiran Company has received a special grant from the Israel Government (Dept. of Commerce and Industry) to mount a "national project" with the target of developing such systems by 1979.

SOLAR PONDS

Work on large-area solar collectors in the form of non-convecting solar ponds, which was discontinued in 1966 when fuel was particularly cheap, has been restarted by The Scientific Research Foundation, with cooperation from most of the institutions of higher learning in the country.

The ponds are designed for temperatures up to 100° so that while little emphasis is being placed on power production, the main goal is for applications involving low grade heat. Apart from the uses in the chemical and process industries, or applications to low-temperature distillation processes, an application being considered is for air-conditioning of large structures such as hot-houses and dwellings (communal rather than single). Target date: 1978.

INSTITUTIONS AND OTHERS ENGAGED IN SOLAR ACTIVITIES

Institutions

Haifa Institute of Technology (Technion)
  (a) Faculty of Architecture

  (b) Building Research Station
  (c) Dept. of Mech. Eng.
Ben Gurion University of the Negev
Weizmann Institute of Science, Rehovot
National Physical Laboratory of Israel, Jerusalem
The Scientific Research Foundation, Jerusalem
The Standards Institution of Israel
The Israel Metheorological Service (measurements only).

Companies*

Herouth Ltd., Tel Aviv
Bar-On – Paz Engineering Ltd., Rishon-Le-Zion
Goldstein – Gonen, Counsulting Engineers, Tel Aviv
Miromit Sun Heaters, Tel Aviv
Tadiran – Israel Electronics Industry Ltd., Tel Aviv
Amcor Ltd., Tel Aviv
Ormat Turbines Ltd., Yavne
Rotoplas, Jerusalem

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* Manufacturers of solar collectors not included unless they have ongoing R & D activity.

ITALIAN SOLAR ENERGY PROGRAM

Mario Silvestri
Consiglio Nazionale delle Richerche

The implementation of the solar energy R and D program sponsored by the CNR (Consiglio Nazionale delle Richerche) was delayed by the government which required that the program be coordinated with the program sponsored by the EEC. Therefore, the start of the national program was delayed until contracts between Italian agencies (universities, companies, etc.) and the EEC Commission were defined. This happened just recently. For 1976 (really the last three months) a total of about $300,000 was allocated, with an additional $150,000 from the EEC. The program will continue in 1977 and after, with an annual expenditure of about $1,000,000 or possibly more.

Most of the CNR program is centered on topics which are basic in principle. They are:

a) Collection and/or retrieval of climatic data to define zones in which solar energy can be used at minimum capital costs for heating, and possibly cooling buildings.
b) Systematic study of a solar energy activated system for heating purposes, taking into account the urban structure of Italy (many apartment houses, very few single family one-or two-story houses).
c) Examination of critical components of the system (collectors, storage systems, piping control panels, back-up systems).
d) Summer refrigeration of buildings through night radiation (with related cold storage systems).

The effort devoted to use of solar energy for heating and cooling of buildings is responsible for 75% of the total expenditure (now and in the future). What remains is devoted to production of mechanical and/or electrical energy through exploitation of solar radiation. That portion of the program is directed toward two accomplishments:

a) Completion of a small (15 KWe) power station, whose solar system has already been built near Genova (S. Therio), with a total mirror surface area of 200 m^2. The mirrors are mechanically driven to follow the path of the sun. To complete the work, the boiler, the turbine and the generator must be built and operated.
b) Direct conversion of solar radiation to electricity by means of solar cells capable of withstanding high flux radiation. In such a system (with photocells, already under development, capable of withstanding radiation fluxes on the order of $10 W/cm^2$), the photocells no longer represent the expensive item in the chain, and specular collectors again become the economic bottleneck.

In summary, the work is just beginning, and a comprehensive picture will be possible only at the next CCMS meeting to be held in 1978.

JAMAICA'S SOLAR ENERGY PROGRAMME

W. R. Ashby
Ministry of Mining and Natural Resources

Things happen slowly in the tropics. For example, it took us a year to sign the Memorandum of Understanding. Similarly, approval has only just been given for the start of our first two projects. These are a project to gain experience in the use of solar crop driers, with a view to commercializing them as soon as possible; and a design study for a low concentration collector to be used for air-conditioning. These projects will be carried out by the university.

Approval is still being sought for the creation of a permanent research and development group to carry out other tasks. Nonetheless, a list of projects has been drawn up awaiting the creation of this group. These aim at prototype or demonstration models in solar cooking, irrigation, air-conditioning, and industrial process stream.

One of the factors affecting the early implementation of these schemes is the acute financial crisis now confronting the government, which, for example, made it impossible for us to attend the Copenhagen meeting. Nonetheless, we are reasonably confident that support will be found for our projects, since it is readily demonstrable that the current energy situation affects Jamaica more acutely than most other countries.

We are also well advanced in the way of making contact with other institutions who share our interests, for example, French and American institutions. In addition, the Organization of American States is in the process of evolving a regional programme for the development of New Sources of Energy, and our efforts are conceived as part of this. But we are still interested in the formation of a sub-group of this body devoted to the interests of tropical countries, as proposed a year ago, and regret that we're not present to contribute to it.

INDUSTRIAL SOLAR ENERGY ACTIVITY IN MONACO

J. H. Millar
Flextube S. A.

OBJECTIVE

Flextube S. A. of Monaco is attempting to develop components and systems for harnessing solar energy to replace or supplement other forms of energy for private houses, apartment buildings, office buildings, hospitals, industrial buildings, swimming pools, etc.

PROJECTS

Projects underway include:

- 3 types of flat plate collectors
- 2 types of concentrating collectors
- 2 greenhouse heating projects using parabolic reflectors and flat plate collectors
- project on anti-freeze and corrosion inhibitors

The flat plate collectors are 2.2 m long and 825 mm wide. Research is underway into different types of surface treatment and covering-glass, plastics, honeycombs, etc. Concentrating collectors are of two types – static and tracking. An additional project is the application of concentrated solar energy to drive desalination equipment.

SURVEY OF ACTIVITIES RELATED TO THE DIRECT THERMAL USE OF SOLAR ENERGY IN THE NETHERLANDS

C. den Ouden
Institute of Applied Physics (TNO)

A national solar energy R & D programme is in preparation under authority of the Dutch National Steering Group for Energy Research (LSEO). This R & D programme will be presented to the government at the beginning of 1977.

In 1975 the LSEO advised the government to supply the following minimum amounts of money for energy research, related to the use of solar energy, wind energy and geothermal energy:

• 1975:	1.2×10^6 DFL. (1 Flf. $\simeq$ 0.4 US $)
• 1976:	18×10^6
• 1977:	50×10^6
• 1978 etc:	50×10^6.

The LSEO has formulated a National Programme for Energy Research (1976). For 1976 they recommended supplying 5.10^6 Dfl. for solar energy research (thermal). A small number of research and development projects are already subsidized by the government.

A survey of projects related to the direct thermal use of solar energy in The Netherlands is listed below.

PROJECTS RELATED TO THE DIRECT THERMAL USE OF SOLAR ENERGY IN THE NETHERLANDS

INSTITUTION	LOCATION	PROJECT TITLE AND SHORT DESCRIPTION	COMPLETION DATE
Building Centre, Rotterdam (Bouwcentrum) Measuring program: Institute of Applied Physics, Delft (TPD–TNO)	OSS	12 energy saving dwellings; 4 of them with 25 m^2 combined collector storage system. Storage in 30 cm thick concrete slabs.	April 1975, construction phase May 1977, evaluation phase
University of Technology, Eindhoven (TH–E)	Eindhoven	solar heated house (prof. Van Koppen) 50 m^2 collector area 5 m^3 storage-tank (water) collector-type: extruded Al-profiles chromium-oxid (Harshaw), single glased	October 1976, construction phase July 1979, evaluation phase
Bredero, Building and Heating and Airconditioning Company Utrecht	Zoetermeer	4 solar heated houses 40 m^2 collector area 2 m^3 storage tank (water)	March 1977, construction phase

PROJECTS RELATED TO THE DIRECT THERMAL USE OF SOLAR ENERGY IN THE NETHERLANDS *(Continued)*

INSTITUTION	LOCATION	PROJECT TITLE AND SHORT DESCRIPTION	COMPLETION DATE
Building Centre Rotterdam Institute of Applied Physics Delft (TPD–TNO)		collector types: 3x steel-collectors with a surface of glass-enamel and tin-oxide. 1x Al-air collector with a chromium-oxide (Harshaw) surface. 4 different heating-systems (floor-, air- and radiator heating)	September 1979, evaluation phase
Philips Energy Systems, Eindhoven	Veldhoven	Several energy saving dwellings; 3 of them with 40 m^2 collector-area 2 m^3 storage-tank (water), combined with a heat-pump. 5 of them with a 5 m^2 collector-area for hot water-supply. Collector types: Mark II, Nys & Vale	April 1977, construction phase 1979 evaluation phase
Municipality of Enschede Architectural design: Connegieter	Enschede	2/3 story-laboratory 400 m^2 collector-area 50-100 m^3 storage-tank (water)	September 1977, construction phase
Eindhoven Un. of Technology		Different collector-types	1979 evaluation phase
VEG-gas institute, Apeldoorn	Apeldoorn	4 solar heated houses 20 m^2 collector-area storage within different floors of the houses. Combined floor-air heating system	September 1977, construction phase

OTHER RESEARCH AND DEVELOPMENT PROJECTS WITHIN UNIVERSITIES AND INSTITUTES

INSTITUTION	LOCATION	PROJECT TITLE AND SHORT DESCRIPTION
Delft University of Technology, Applied Physics Laboratory, Department of Heat and Mass Transfer	Delft	Fundamental and experimental study on free convection between inclined surfaces. Fundamental and experimental study on selective surfaces.
Delft University of Technology, Department of Mechanical Engineering	Delft	Cooling with solar energy.
Eindhoven University of Technology	Eindhoven	Measurement of solar radiation data for thermal comfort and response studies. Possibilities for long-term storage.
Institute of Applied Physics (TPD–TNO)	Delft	Development of solar collectors with a long life-time. Development of a computer programme for the prediction of system performance with 10-year hourly measured data. Development of storage-system based on p.c.m. materials
Organization for Applied Scientific Research, TNO	Apeldoorn	Development of a solar assisted heat-pump system.
University of Groningen Applied Physics Laboratory	Groningen	Flat-plate collectors employing the heat pipe principle.
Philips, Applied Physics Laboratory	Eindhoven	Concentrating collectors → stirling cycle → mech./el. energy

SOLAR ENERGY IN SAUDI ARABIA

F. A. Somait
University of Petroleum and Minerals

At the CCMS Palo Alto meeting (August 1975), Professor Ketanni outlined the activities on solar energy in Saudi Arabia. Additional activities that have taken place since then are:

1. The newly formed King Faisal Foundation which is planning a program on solar energy heating and cooling.
2. The Ministry of Petroleum and Mineral Resources will have a small department on Solar Energy as part of the planned National Nuclear Research Center.
3. The Research Department of the Saline Water Conversion Corporation is actively studying the possibility of utilizing solar energy as a supplementary energy form for sea water distillation.
4. Saudi Arabia is funding an experimental solar energy supported school in the U.S.A.

Saudi Arabia will benefit from investigating alternative energy sources in two ways; the first being the immediate technical know-how and the second is ability to meet energy requirements when the fossil fuels run out.

For the immediate future, it is expected that public use of solar energy will be limited to remote desert areas where small desalination plants could be installed to produce potable water.

In conclusion, Saudi Arabia is in favour of international cooperation and would like to see the world less dependent on fossil fuels.

REVIEW OF SOLAR ENERGY PROJECTS IN SPAIN

J. Fernandez-Sintes
Comision Nacional de Energias Especiales

The involvement of private industry in solar energy applications is rapidly expanding in Spain as the price of conventional fuels and electric energy increases and the market for alternative sources of energy becomes better defined.

About ten private firms, most of them air-conditioning or heating equipment manufacturers, are currently producing and beginning to commercialize flat plate water collectors. These collectors are of conventional design and are being installed mainly for domestic hot water supply, heating of pools,and, in at least one case, for the space-heating of a greenhouse. The production of these panels have reached a level on the order of 10,000 sq. meters per year with a marketing price between 120 and 150 US$ per sq.m.

A performance testing laboratory for flat plate collectors is currently in operation at the Instituto Nacional de Tecnica Aeroespacial (INTA). Following the test procedures recommended by the U.S. Bureau of Standards, four different water collectors have already been evaluated and four others will be tested shortly.

Large commercial firms are also beginning to show interest in the solar energy market. One of them is building for its headquarters, in the downtown business area of Madrid, a high-rise office building solar-assisted by an air collector system which will supply about ten percent of the space heating requirements. Passive systems and energy conservation measures are increasingly being incorporated by architects in their projects. A recent regulation issued by the Ministry of Housing specifies maximum allowable heat transmission coefficients in buildings.

The Department of Energy and Propulsion at INTA is carrying out research work in the development of a computer simulation program for the evaluation of solar components and systems for the heating and cooling of buildings. The same Department is also working on the project of a solar-assisted heat-pump heating and cooling system with financial support from the Ministry of Industry and the Advisory Committee for Scientific and Technical Research.

In addition, Spain participates, within the International Energy Agency, in the five sub-projects defined for the development of heating and cooling systems for buildings. This participation is channeled through the combined efforts of INTA and the National Meteorological Service. To support these projects, the Spanish Energy Research Center (Centro de Estudios de la Energia) has granted about $400,000 for a period of three years.

A solar desalination plant of 2200 sq. meters is being constructed by INTA on the Island of Tabarca, near Alicante. Designed for prefabrication, the estimated cost is expected to be below $30 per sq. m.

Spain is also participating, within the International Energy Agency, in the 500 KW solar power plant project with a contribution of 40,000 US$ as part of the total cost of the project phase which is on the order of 300,000 US$. In addition, if the project is realized, Spain will contribute a location site in Almeria which has already been tentatively preselected.

In relation to cooperative programs, INTA of Spain and MBB of Germany are considering, within the Agreement of Technical Cooperation between Spain and Germany, a cooperative testing program of a 10 KW power plant with 300 sq. meters of flat collectors, freon working fluid and a Linde-type rotative expansor.

Besides the development activities which have been summarized, basic research on a variety of subjects directly related to solar energy is being conducted at various research institutions and universities. The **Consejo Superior de Investigaciones** Cientificas carries out work on selective surfaces, desalination, and other fields. At the Esceula Técnica Superior de Telecommunicación de Madrid an innovative research program on photovoltaics is underway. Basic research on photosynthesis is being conducted at the University of Seville.

Spain and the United States have recently signed a Treaty which incorporates a program of technological assistance within which the development of solar energy applications is specifically mentioned as one of the fields of cooperation. This program will undoubtedly imply a significant vitalization of activities in the solar energy field.

SUMMARY OF SWEDISH SOLAR ENERGY RESEARCH WITH EMPHASIS ON THE BUILDING SECTOR

Lars Engstrom
Uhlin & Malm Architects

INTRODUCTION

As was stated during the CCMS Solar Energy Experts Meeting in Palo Alto, August 1975, the guidelines for Sweden's energy policy were laid down by the Parliament in May 1975. A revision will take place in spring 1978. The aim, therefore, is to sum up R&D from the whole energy field in March 1977 as a basis for the new decisions to be made a year later.

The present R&D efforts might be summarized as concentrated on energy conservation. Several bills with such aims have recently been passed and more are underway. Nuclear power is a very controversial question cutting through all political parties and a referendum is discussed. R&D on alternative energy sources, on the other hand, are unanimously estimated as necessary, and there seems to be a trend towards a concentration on solar energy for building purposes.

SWEDISH AGENCIES FOR ENERGY RESEARCH AND DEVELOPMENT

Statens rad for byggnadsforskning, BFR (the Council for Building Research) with few exceptions covers the whole field of R&D for buildings and the built environment, and thus has the main responsibility for solar energy applications such as a space heating and hot water production.

Styrelsen for teknisk utveckling, STU (the Board for Technical Development), deals with industrial and commercial applied R&D and thus treats the hardware side of solar energy.

Namnden for energiproduktionsforskning, NE (the National Board for Energy Source Development), was formed last fall and works through planning groups, one of which is dedicated to solar energy applications such as production of electricity, hydrogen and hydrocarbonfuels.

The cooperation between these three authorities is of course very intricate but, on the whole, the border lines in the field of energy R&D now seem much better defined than only a year ago.

INTERNATIONAL COOPERATION

As was pointed out in Palo Alto, Swedish experience in the application of solar heating systems to space heating is very limited. Dependence on the bulk of information abroad therefore must be great. Early Swedish contributions to the international know-how might be made especially in fields such as fenestration and optimization formulas.

The Council for Building Research for many years has sponsored translations of reports into English and is planning to intensify such activities especially in the field of solar energy. The CCMS system reporting format has been carefully studied in this context, and at least three demonstration projects of those underway will be reported in English.

Sweden is represented in all the five sub-groups of the IEA Solar Energy Working Party, and Swedish involvement especially in task 5 (Use of Existing Meteorological Information for Solar Energy Application) is worth noting.

Collaboration in technical sciences between France and Sweden has a long tradition and has been intensified in the field of energy research during the last few years. Most of the bilateral efforts in solar energy R&D are made in photochemistry with energy production as the goal, but joint research on selective surfaces may be of use in space heating applications as well.

On November 1st of this year the Solar Energy Association of Scandinavia (SEAS) will be formally founded in Stockholm. SEAS will be attached to the International Solar Energy Society. Chairman of the interim board is Professor Vagn Korsgaard, Copenhagen.

R&D PROGRAM FOR SOLAR HEATING OF BUILDINGS

A program investigation into solar space heating was noted in Palo Alto, and it was mentioned that the report was undergoing a review process before a revision. As development is very rapid, it was felt that a final version should wait until as much experience as possible had been gathered before the dead-line of March 1977, when all basic facts for the political energy decisions of 1978 are to be available.

A major complaint noted during the review process of the program investigation report concerned the small contribution proposed for R&D on solar heating in existing buildings. This, of course, is a very important problem, and a number of preliminary studies have been initiated.

One of many problems pointed out in Palo Alto was a supposed shortage of highly qualified researchers in Sweden, and this was one of the reasons for limiting the funds to some one million Swedish kronor a year (US $200 - 250,000). Actual R&D in fiscal year 1975-76 was supported with SKr 0.96 M, but is budgeted to Skr 1.3 M 1976-77 and Skr 1.5 M 1977-78. The problem of recruiting qualified research workers is dealt with mainly by signing long-term contracts between the authorities and appropriate university institutions.

A proof of the increasing importance attached to solar space heating is the formation of a special secretariat and a reference-group within the Council for Building Research.

ACTUAL R&D ON SOLAR HEATING

Systematization and adaptation of meteorological data to solar energy applications are recognized as tasks of fundamental importance, and work is carried out both in national scope and, as mentioned above, within the IEA cooperation.

The application which looks most promising for Sweden in the short run is solar heated tap water, and several studies are being carried out. Sweden has a considerable number of week-end houses inhabited mainly during the warm season and heated, if at all, electrically. Solar heated tap water then is a very intriguing option. It is also probable that solar collectors for tap water production may be realistic as add-on-systems in existing buildings. It is known that a big company very soon will make a small series of such collectors commercially available. The absorber is made of copper, and the water is used for direct consumption. The main characteristic is that the copper is extremely thin which will, of course, reduce the cost.

A three-year project jointly carried out by the Institutions of Building Technology and Physical Chemistry at the Technical University of Stockholm is running into its third year. Heat storage in eutectic salts is studied, and experiments in laboratory scale have served to exclude a number of theoretically conceivable alternatives. Large scale tests of promising methods are being planned. Several series of parallel tests on solar collectors will soon be carried out. Research on selective surfaces was originally included in the R & D program, but international know-how and Swedish research carried out at other institutions in this particular field have focused the attention on storage and system problems.

Two full-scale, solar heated demonstration houses of different characteristics have been tested and another is underway. They were described during the presentation of Special Format Reports.

Collaboration between seven institutions is being carried out at the Technical University of Lund. The aim is to conduct thorough studies of building projects with minimized demands of resources during the building process, as well as after. Solar energy application is one of many detailed problems studied. Full scale testing of a block of buildings is the ultimate goal.

R&D ON SOLAR HEATING IN THE LONG TERM VIEW

The research carried out so far has served to build a basic competence and the possibility of concentration on certain lines of development. In 1978, the experiences from the first solar houses will be summed up and new houses are expected to be under way. Applications to multifamily houses are also judged as possible at that time. Large-scale use of solar heating systems, of course, must be supported by industrial involvement, and this is not expected to be achieved to any considerable extent until the first years of the next decade.

R&D ON SOLAR ENERGY PRODUCTION – A SUMMARY

The National Board for Energy Source Development has commissioned a planning group to look into possible R&D fields of solar energy production. Although Sweden has an average of 50% diffuse light, and concentration devices thus seem rather meaningless, the planning group has recommended Swedish participation in the proposed IEA Solar Thermal Demonstration Plant. It is felt that the spin-off effect on solar energy R&D within the country from such involvement would be of great value, as well as broadening the international contacts considerably.

A study of the potential of large scale application of photovoltaic silicon cells with views to the system as a whole has been recommended. Solar heated low temperature processes for industry and agriculture also seem interesting.

Sweden has a small, but very competent, team of photochemists. They will be encouraged to engage in R&D in the solar energy field, but obviously no applications of significance can be expected in the short term perspective.

A number of visionary photobiological lines of development have been discussed, some of which will be supported as basic research projects. Photobiological applications to waste disposal processes with methane-production as a goal seem comprehensible within the next few years and have been given priority by the planning group.

SOLAR ENERGY PROGRAM OF TURKEY

Department of Energy
Ministry of Energy and Natural Resources

INTRODUCTION

Solar energy, the use of which has so far been insignificant in Turkey, can be utilized to make a significant impact as a new energy source due to the attractive geographic climatology. Turkey is privileged with an outstanding potential of solar energy. Average yearly intensity of solar radiation is 316 Ly/day, distributed as following according to months:

Months	Radiation Int. Ly/day	Months	Radiation Int. Ly/day
January	150.01	July	503.13
February	189.01	August	457.16
March	265.00	September	375.26
April	258.93	October	269.09
May	428.57	November	179.06
June	485.23	December	132.04

Solar energy has been popularly used for drying vegetables and fruit, for heating water and for some other purposes. Since 1973, however, a "Solar Energy Coordination Board" has been established with the participation of several ministries, governmental organizations and Universities, to promote the efficient use of solar energy, and to coordinate the overall solar energy research and development.

NATIONAL SOLAR PROGRAM

Work on solar energy systems is organized in two categories:

Short and Medium Term Development

To establish solar laboratories, solarimetry (rehabilitation of existing solar energy data and mapping of total solar radiation for the whole territory of Turkey), the production of solar water heaters, the reconstruction of greenhouses to better adapt them to solar conditions, the use of solar energy for cooking purposes, the production of air heaters (agricultural and industrial), improving vegetable and fruit drying techniques, heating of buildings, production of solar pumps, distillation units for the desalination of water, solar cooling systems, research in solar cells.

Long Term Development

The design and construction of solar ponds and solar furnaces, construction of thermal power plants, research in photovoltaic and photo-chemical conversions, production of metane and hydrogen by means of thermochemical processes.

In order to achieve these objectives, a formal solar energy program, as part of the national energy programme and 4th Five-Year Development Plan, has been formulated. The most immediate applications would be for water heating, drying of agricultural products, heating of greenhouses and heating of buildings.

CURRENT PROJECTS

A number of solar energy projects are currently being undertaken. Outstanding among these is a government sponsored project for setting up a "Solar Energy Research Center" under the administration of the Mineral Research and Exploration Institute. The objective of the center is the investigation of all means of harnessing solar radiation for the benefit of Turkey. (Detailed explanation is given below).

A solar-heated building project is also planned to be constructed in Ankara. The purpose of this work is to establish the techniques of effective utilization of the space heating of buildings. Initial emphasis will be on modelling the system performance and architectural integration.

Up to now, prototypes of solar water heaters suitable for Turkey have been developed. A few commercial firms construct water heaters, and sales are rising quite rapidly. They are installed in homes, buildings and tourist facilities. Storage capacities vary between 90 - 9000 liters. Solar water heating is clearly the most promising application at present, and the technology of capability of the country is good enough to allow the development of such techniques on a national basis. Studies are underway for cost and widespread use.

At the Middle East Technical University in Ankara, the evaluation and testing of a new, matrix type of plate air heater for dehydration of fruits and vegetables and the development of an original drying chamber with translucent walls have been performed. With the experience and insight gained from this laboratory project, an economical village-type dehydration model was designed and constructed. Favorable results were obtained.

In the solar energy laboratory of the Farm Power Machinery Department, Faculty of Agriculture, University of Ankara, solar water and air heaters have been developed related to solar energy utilization in villages.

Solarimetry studies are underway at the Turkish Scientific and Research Council. A distribution map for total horizontal radiation energy (monthly, annually and seasonally) has been prepared. A computer programme has been carried out regarding solar angles and the amount of solar energy through a single window for latitudes 36° N, 38° N, 40 ° N, 42° N; for 1st, 11th, 21st days of the month and for every hour of the day. Other computer programmes for solar energy optimization are also underway.

Scientific research work is underway at Adana, Ege and Istanbul Universities on projects such as solar water heaters, collector development, heating of greenhouses and also solar energy power generation by means of photocells.

MARMARIS SOLAR ENERGY RESEARCH CENTER

The research center is planned to be established near Marmaris in West Anatolia and will also function as a meeting place of international symposiums. COMPLES, which has been informed about the project, intends to establish a new pilot station there. Construction of the center is expected to be completed at the end of 1976, and research studies are to begin in the summer of 1977.

The research center will cover quite a vast area (780,00 m^2) and lie at the bottom of a small bay which opens out to South. The area contains a considerably large bare hill which would serve as a testing platform.

The laboratories and work-shops will be set up on the southern and southwest side of the hill such that their roofs will cast no shadow onto the platform. On one of the steepest slopes of the hill between the sea-coast and the hill, several attics will be constructed for demonstration purposes due to their very advantageous insolation possibilities. Moreover, a desalination unit will be established at the bottom of the hill for production of drinking water.

The main platform will be concrete and be provided with necessary supports and auxiliary establishments. A small meteorological station will be constructed on the open part of the platform and the speed of wind will be measured by means of an annemometer.

The main meteorological station of the research center will be established on the highest hill of the surrounding area under the administration of the State Meteorological Works. The proposed studies will be indirectly related to solar energy techniques.

Since solar energy technology is yet in an evolutionary stage, the laboratories are planned to be constructed in such a way that all necessary modifications could possibly be made in the future. Accordingly, the connecting doors will be movable and the fixed establishments will be set up on main doors. The laboratories may be enlarged in the future.

The work-shops will be established near to the laboratories and include the following ones:

a) mechanical
b) health
c) carpentry
d) electrical and electronics

There will be another laboratory of which one part faces the South and is covered with disconnectable glass. Accordingly sun rays, after being reflected by means of the reflectors set up on the outer part, would diffuse into the laboratory horizontally.

The installation of the first solar power plant is planned for this center. Its location would be closer to the coast in order to discharge the cooling water to the open sea.

The research activities of the center will not be restricted. All kinds of scientific research, general studies, demonstration, training, applied and solar engineering studies will be undertaken. However, personnel training will be of special importance.

The planned research activities can be summarized as follows:

A. Small-scale applications for the purpose of energy conservation.

1. Water heating and space heating requirement of villages which do not have any electricity and domestic water facilities.
2. Water heating and heating requirements of villages which have electricity but do not have domestic water facilities.
3. Domestic water heating and space heating of modern houses.

4. Heating and cooling of modern houses
5. For rural area, construction of autonomous solar plants and production of mechanical energy for pumping purposes.

B. Large scale applications involving energy conversion.

1. Construction of large solar plants (5-10 MW) by using the sea as a cold water source.
2. Mixed production establishments: Production of electricity by means of solar regeneration of low temperature (90-100°C) natural steam by simultaneous use of geothermal and solar energy.

C. General Studies

1. Documentation studies
    - construction of training and demonstration stations
2. Synthesis studies
    - Investigation of the properties of several collectors and related demonstrations
    - Production of hydrogen by electrolysis
    - Heating of greenhouses
    - Storing of solar energy

The main objective of the solar heating and cooling portion of the research program is development of solar heating and/or cooling systems for the types of houses mentioned in A. 1-4, above.

For heating those country houses with no water or electricity, use of the "collector-storage wall system" is planned. (The one which Mr. Trombe and his colleagues have built at Odeillo, France can be given as a reference.)

For houses with electricity but no water, a basic hot air system is going to be used. Either vertical walls facing south or other conventional collectors will be used for collecting solar energy. The transporting medium will be air and a pebble-bed will be used as a storage unit.

The system for heating small dwellings and apartment buildings is essentially composed of three parts, namely: Solar collectors, the storage unit and a supplementary heat source. Solar collectors will be flat-plate and movable. The storage unit will consist of a large hot water tank where water will be used as the heat transferring fluid. However, all other methods besides hot-water storage such as pebble beds and chemical substances will also be considered. Due to high cost of unit heat provided by the solar equipment alone, an auxiliary heat source will be used for supplementing extremely high heating demands.

As the last step of the project, we propose research studies on solar cooling systems in small dwellings and apartment buildings with water and electricity. Some kind of a collector-radiator-heat pump system using uncovered collectors as daytime collectors and nightime radiators will be considered. (This system has also been tried in several places especially in Tokyo by Yangimacki and in Arizona by Bliss.)

INTERNATIONAL COOPERATION

Coordination with international solar energy associations is carried out intensively and effectively. For the purpose of more beneficial coordination of international activities, a "Turkish National Committee of Solar Energy" is being formed. Turkey, being a member country in CCMS and COMPLES, wishes to participate actively in the international pilot studies in accordance with the programmatic goals of her solar energy R + D programme. We certainly believe that our "Solar Energy Research Center" will also be beneficial for the Mediterranean countries of the CCMS pilot study. It is also worth considering the possibility of extending the scope of the CCMS Solar Energy Pilot Study to other solar energy activities besides the heating and cooling systems in buildings.

REVIEW OF THE UNITED STATES SOLAR HEATING AND COOLING PROGRAM

Frederick H. Morse
U.S. Energy Research and Development Administration
Division of Solar Energy

INTRODUCTION

This paper presents an overview of the United States Solar Heating and Cooling Program. It is a summary of the information contained in five documents which were only in draft form at the time of this meeting. These five documents were subsequently released and are listed in the Reference section (1, 2, 3, 4, 5).

The major elements of the Energy Research and Development Administration's Solar Heating and Cooling Program are:

- Research and Development
- Development for Building Demonstrations
- Residential Buildings Demonstrations
- Commercial Buildings Demonstrations
- Agricultural and Industrial Process Demonstrations

Briefly, the Research and Development program seeks to provide components and systems having improved performance and/or lower cost. The Development for Building Demonstrations is to provide those services necessary to facilitate the bringing of advanced components and systems to the market. The Demonstration programs are to use available technology to demonstrate the ability of various solar energy systems to meet the thermal energy need of residential and commercial buildings and of agricultural and industrial processes.

The overall goal of the Solar Heating and Cooling Program is to stimulate the advancement of an industrial, commercial and professional capability for producing and distributing various solar energy systems, thus reducing the demand on fossil fuel supplies through widespread use in heating and cooling of residential and commercial buildings, for service and process hot water, and for the thermal needs of various agricultural and industrial processes. ERDA 76-6(1) describes the Solar Heating and Cooling Program in detail.

The following objectives provide qualitative and quantitative outcomes of the program which are assessed to be achievable and are in accordance with the laws that govern ERDA's Solar Program.

1. Stimulate solar energy applications for heating and cooling of buildings to provide 7% of the total national energy requirements by the year 2000. The fuel savings that would result with achievement of this objective are estimated to be 10Q or about 5.0 million barrels of oil per day.
2. Demonstrate the feasibility of solar heating of buildings by 1977 and combined solar heating and cooling of buildings by 1979 for residential and commercial buildings in existing and new construction applications.

3. Implement, by the end of 1976, a directed comprehensive program for research and development activities for improved and new solar heating and cooling systems and system concepts. Substantial cost reductions will be achieved by the use of lower cost materials, the development of optimized systems, and increased performance of the key components.
4. Establish, by the end of 1976, a data bank and mechanisms for collection and widespread dissemination of information on solar heating and cooling, including technical, environmental and socio-economic factors.
5. Develop, by the end of 1978, solar system performance criteria and standards for the production and installation of solar heating and cooling systems and components with appropriate provisions for consumer protection.

6. Identify, by the end of 1979, the necessary incentives and other actions necessary to eliminate or mitigate utility, legal regulatory and other barriers and to make solar heating and cooling applications cost-effective on a life-cycle cost basis for a large segment of the potential market.

RESEARCH AND DEVELOPMENT PROGRAM

Program Objective

The objective of the current solar heating and cooling R & D program is to assist in the creation of a viable solar energy industry by improving the cost effectiveness of solar energy systems.

FY 1976 Projects

In FY 1976, the R & D Program expanded from 58 projects to 76. Most of the projects are directed at providing improved performance in components, improved manufacturing techniques, and/or lower initial and maintenance costs. The projects in each of the program elements are categorized in the following paragraphs. A brief description of each of the projects is presented in ERDA 76-145(2).

Collectors – There are twenty-four collector projects.They emphasize the development of liquid-heating or air-heating flat plate collectors, honeycomb structures, vacuum tube collectors, fixed mirror concentrators, V-trough reflectors, selective coatings for absorber surfaces, fundamental heat transfer studies, and the testing and evaluation of collector materials.

Thermal Storage/Heat Exchange – Six projects concern thermal energy storage or heat exchange. Emphasis is on study of phase-change materials, improved heat exchangers, and seasonal storage of solar heated water.

Heat Pumps – Of the two solar-assisted heat pump projects, one concerns the development of a heat pump with pivoting tip vane rotating equipment, and one concerns a unitary heat pump system designed for commercial buildings.

Air Conditioning – Air conditioning projects include studies of a silica gel absorption machine, development and testing of two solar Rankine cooling units, evaluation of a regenerative gas cooling cycle, and the development of a Nitinol engine.

System Analysis – The nineteen system analysis projects include research on passive solar heating systems, computer modeling and simulations for a variety of solar heating and cooling systems, acquisition of data on system performance, and modeling for life cycle cost analysis of solar heated and cooled buildings.

Controls – There are two controls projects. The first is an analysis of system and interface problems in low cost solar heating and ammonia-water absorption cooling systems. The second project concerns adaptive controls for a solar heating and cooling system.

Program Support – The R & D program includes nineteen program support projects. The projects concern the work of the support laboratories, workshops, and program management personnel.

Program Status

Some of the most significant recent accomplishments in the R & D program are as follows:

- Preparation of a comprehensive R & D Plan.
- Development and publication of thermal performance test procedures for collectors and storage subsystems.
- Development and testing of a prototype steel collector suitable for use as a building roof or wall.
- Development and testing of a high performance evacuated tubular glass collector.
- Demonstration of significant improvement in the performance of flat plate collectors through the use of honeycombs for suppression of thermal losses.
- Identification of several promising phase-change thermal energy storage encapsulation methods.
- Development of a low temperature, high performance, absorption, air conditioning machine for residential buildings.
- Development of a Rankine powered, vapor compression, air conditioning machine.
- Evaluation of first year performance data on well instrumented solar heating and cooling systems.
- Development of economic predictions and simplified design methods based on a detailed system simulation program.

Table 1 lists the institution, project manager and title of all current R & D projects.

FUTURE R & D PROGRAM

A series of technology review meetings was called by the Los Alamos Scientific Laboratory during the winter of 1975-76. The meetings were held to assess the state of the art, identify impediments to improved performance and reduced costs, and recommend short-and long-term means (R&D tasks) for removing such impediments. Participants included representatives from industry, universities, and Government laboratories and agencies.

In these meetings and in other discussions, the status of the national solar heating and cooling effort was defined. The following points became clear:

- The major problem to be addressed is cost effectiveness.
- The state of the art varies greatly for different components and applications. Solar cooling technology is generally less developed than that for solar heating.
- Because the applications and climatic zones are quite varied, careful analysis is required to determine the most cost-effective approaches.
- Cost-effective retrofit systems do not exist, nor are techniques available for optimizing retrofit design.

The meetings and discussions also uncovered many other problems that must be solved before the technology can be significantly advanced.

As a result of these meetings, it was decided that ERDA's present components-oriented R & D program which has contributed significantly to the present state of technology, should be strengthened by the initiation of an ERDA-directed, applications-oriented R & D program. This program is fully described in ERDA 76-144 (3).

The specific objective of the directed R & D program is to provide the solar energy industry and other users with the materials, components, and information needed for cost-effective solar heating and cooling systems. The directed R & D plan defines promising approaches, called paths, for achieving this objective and outlines a systematic program for providing materials, components, and systems designed to establish the cost effectiveness of each approach as rapidly as possible.

The directed R & D plan (in *ERDA 76-144*) contains ten paths, two for hot water and four each for space heating and coolings. Each path links a method of solar energy collection or rejection with a specific application. The ten paths are listed in *Table 2*.

In order to develop cost-effective technology for achieving the path applications, various tasks must be accomplished. Approximately 275 such tasks have been identified and placed in the following five categories: collectors, storage and heat exchangers, air conditioning and heat pumps, systems and controls, and non-engineering aspects.

The task descriptions in ERDA 76-144 are sufficiently detailed to indicate work that must be done but broad enough to give the program flexibility. Many of the tasks are common to several of the paths. In each path the tasks are arranged in sequence, so that the paths develop in a logical manner.

The shift in emphasis in the directed program from components to applications will be accompanied by a change in the method of implementation. While the present R & D program is based on unsolicited proposals, the program for the directed plan will be based on competitive solicitations, including Program Research and Development Announcements (PRDAs) and Requests for Proposal (RFPs). These solicitations will provide an opportunity for interested parties to propose projects for R & D on specific aspects of the program. The involvement of industry, universities, small businesses, and various Government organizations is expected to continue, with project support being provided by the national laboratories.

Since the R & D program of the Division of Solar Energy is part of the total ERDA energy program, it has many points of impact on other ERDA organizations and other Federal agencies. The implementation of the directed R & D program will therefore be coordinated with all appropriate groups.

During the winter of 1976-1977, a series of PRDAs will be released covering a wide range of R & D work for the solar heating and cooling of buildings. The subjects of these planned PRDAs are as follows:

- Thermal energy storage subsystems
- Solar-assisted heat pump projects.
- Systems and controls.
- Solar-activated cooling projects.
- Passive and hybrid systems.
- Non-concentrating collectors.
- Concentrating or evacuated collectors.
- Solar collector material and fluids.

Table 1

SOLAR HEATING AND COOLING RESEARCH AND DEVELOPMENT PROJECTS SUPPORTED IN FY 1976

COLLECTORS

INSTITUTION	PROJECT MANAGER	TITLE
Battelle Northwest Lab.	T.D. Chikalla	Development of Improved Cover Plates for Solar Collectors
California, Univ. of – Los Angeles	H. Buchberg	Transparent Glass Honeycomb Structures for Energy Loss Control, Phase II
Center for the Enrivonment & Man	Lloyd Shaffer	Viscosity Stabilized Solar Ponds, Phase I
Corning Glass Company	Ugur Ortabasi	Research on Evacuated Tubular Solar Collectors Utilizing a Heat Pipe
Dynatherm Corporation	Walter Bienert	Research on Flat Plate Solar Collectors Employing the Heat Pipe Principle
Georgia Institute of Tech.	Richard Williams	Development of a Solar Heat Supply System with Fixed Mirror Concentrators, Phase II
Giner, Inc.	Jose Giner	Study of Corrosion and its Control in Aluminum Solar Collectors
Honeywell, Inc.	Phillip Kruger	Low Cost Solar Air Heaters
Honeywell, Inc.	Henry Mar	Optimization of Coatings for Flat Plate Solar Collectors, Phase II
Houston, Univ. of	J. Howell and R. Bannerot	Analysis, Design, Fabrication and Testing of Moderately Concentrating Solar Energy Collectors, Phase II
Illionis Institute of Tech. Research Institute	J. Gilligan	Exposure Testing and Evaluation of Solar Collector Materials
Jet Propulsion Lab.	Vincent Truscello	A Fixed Tilt Solar Collector Employing Reversible Vee-Trough Reflectors and Vacuum Tube Receivers
Lehigh University	Dale Simpson	Low Cost Solar Collector of Packed Bed Design
Lockheed Palo Alto Res. Lab.	Ken Marshall	Optimization of Thin Film Transparent Plastic Honeycomb Covered Flat Plate Collectors, Phase II
Los Alamos Scientific Lab.	J.D. Balcomb	Research on Integrated Solar Collector Roof Structures, Phase II
Massachusetts Inst. of Tech.	Shawn Buckley	Development and Evaluation of Thermic Diode Solar Panels for Building Heating and Cooling, Phase II

COLLECTORS (Cont.)

INSTITUTION	PROJECT MANAGER	TITLE
National Bureau for Standards	Elmer Streed	Development of Methods of Evaluation and Test Procedures for Solar Collectors and Thermal Storage Devices, Phase III
Owens Illinois	Kenneth Moan	Evaluation of an All-Glass, Evacuated, Tubular, Non-focusing, Non-tracking, Air-Heating Solar Collector Array
Polyset, Inc.	John Bradley	Development of A Freeze Tolerant Solar Water Heater Using Crosslinked Polyethylene as a Material of Construction
Solaron Corporation	Les Shaw	Improvement of Solar Air Heaters
Texas A&M Res. Foundation	James Stricklin and Howard Chevalier	Structural Integrity of Solar Collectors
Virginia, Univ. of	J.T. Beard	Engineering Analysis and Testing of Water-Trickle Solar Collector
Waterloo, Univ. of	K.G.T. Hollands	Methods for Reducing Heat Losses from Flat Plate Solar Collectors, Phase II
Wisconsin, Univ. of	John Mitchell and M.M. El-Wakil	Interferometric Study of Natural Convection Characteristics of Flat-Plate and Vee-Corrugated Solar Collectors

THERMAL STORAGE/HEAT EXCHANGERS

INSTITUTION	PROJECT MANAGER	TITLE
Altas Corporation	Francis de Winter	Investigation of Methods to Transfer Heat from Solar Liquid-Heating Collectors to Heat Storage Tanks
Colorado State University	John C. Ward	Direct Contact Liquid-Liquid Heat Exchangers for Solar Heated and Cooled Buildings
General Electric Company	A.T. Tweedie	Two Component Thermal Material Study, Phase II
National Bureau of Standards	Elmer Streed	Development of Methods for Evaluation and Test Procedures for Solar Collectors and Thermal Storage Devices, Phase III
North Carolina State Univ.	J.A. Bailey	Research on Solar Energy Storage Subsystems Utilizing the Latent Heat of Phase Change of Certain Organic Materials, Phase II
Virginia, Univ. of	J.T. Beard	Annual Collection and Storage of Solar-Heated Water for Heating of Buildings

HEAT PUMPS

INSTITUTION	PROJECT MANAGER	TITLE
Battelle Columbus Labs.	Robert D. Fischer	A Solar Powered Heat Pump Utilizing Pivoting Tip Vane Rotating Equipment, Phase II
Syracuse University	Eugene Drucker	Commercial Building Unitary Heat Pump System with Solar Heating, Phase II

AIR CONDITIONING

INSTITUTION	PROJECT MANAGER	TITLE
ARKLA Industries, Inc.	Richard Merrick	Engineering, Design, Construction and Testing of a Salt Water Absorption Cooling Unit Optimized for Use with a Solar Collector Heat Source, Phase II
Center for the Environment and Man	Peter Lunde	Studies of Silica Gel Absorption for the Dehumidification and Air Conditioning of Buildings with Solar Energy
Hittman Associates, Inc.	Henry Curran	Assessment of Solar Powered Cooling of Buildings
Lawrence Berkeley Lab.	J.M. Hollander and R. Banks	Studies of Solar Energy Conversion Systems Using Nitinol Engines for the Cooling of Buildings, Phase II
Los Alamos Scientific Lab.	J.D. Balcomb	Solar Rankine Cooling Unit Installation in Large Building, Phase II
Maryland, Univ. of	Redfield Allen	Performance Studies of Solar Absorption Air Conditioning Systems, Phase II
RCA Corporation	Ben Shelpuk	Air Conditioning Using a Regenerative Gas Cycle, Phase II
United Technologies Research Center	Frank Biancardi	Solar Powered Turbocompressor (Rankine Cycle) Air Conditioning System

SYSTEM ANALYSIS

INSTITUTION	PROJECT MANAGER	TITLE
Ayres & Hayakawa Energy Mgmt.	J. Mark Ayres	Rehabilitation and Testing of Skytherm Atascadero House
Colorado State University	George O. Lof	Systems Modification and Refinement for Residential Solar Heating and Cooling
Colorado State University	Susumu Karaki	Evaluation of a Residential Solar Air Heating System

SYSTEM ANALYSIS (Cont.)

INSTITUTION	PROJECT MANAGER	TITLE
Colorado State University	John C. Ward	Evaluation of Maintenance Cost and Mechanical Improvement of the Solar Equipment in Denver House, Phase II
Colorado State University	Dan S. Ward	Residential Solar Heating and Cooling Using Evacuated Tube Solar Collectors
Colorado State University	William Duff	Evaluation of the Corning and Philips High Performance Collectors in the Residential Solar Heating and Cooling System
Delaware, Univ. of	Jerome Scott	Consumer Demand Analysis – Solar Heating and Cooling of Buildings
General Electric Company	Al Jacobsen	Exploration, Design, Construction and Evaluation of Solar Energy Systems for the Heating and Cooling of Mobile Homes, Phase II and Phase III
George Washington University	Ali Kiper	Evaluation of a Solar Heating and Cooling System Using a Trickle Collector and Combined Water Rockbed Storage
Gershon Meckler Assoc., P.C.	Gershon Meckler	Parameter Grouping and Regionalizing to Simplify Solar Life Cycle Cost Models for Application to Solar Heating and Cooling of Buildings
Los Alamos Scientific Lab.	J.D. Balcomb	Research on Passive Solar Heating of Buildings
Los Alamos Scientific Lab.	J.D. Balcomb	Solar Energy System Optimization Study for the Los Alamos National Security and Resources Study Center
Los Alamos Scientific Lab.	J.D. Balcomb	National Security and Resources Study Center Instrumentation
Martin Marietta Corp.	R.T. Giellis	Solar Heating and Cooling Computer Analysis – A Simplified Sizing Design Method for Non-Engineers
Pennsylvania State Univ.	Stanley Gilman	Evaluation of the Solar Building, Albuquerque, New Mexico
Solar Environmental Engineering Co., Inc.	C. Byron Winn	Solar House Design Program Validation
Wisconsin, Univ. of	John Duffie	Computer Modeling and Simulation of Solar Heating and Cooling Systems
Wormser Scientific Corp.	Eric Wormser	Evaluation of Solar Energy Heating and Cooling System Employing Pyramidal Optics Solar Collection System

CONTROLS

INSTITUTION	PROJECT MANAGER	TITLE
Lawrence Berkeley Lab. – Univ. of California	Michael Wahlig	Low Cost Control System and Interface Problems of Combined Solar Heating and Ammonia-Water Absorption Cooling Systems
Los Alamos Scientific Lab.	James P. Shipley	Adaptive Control for Energy Conservation

SUPPORTING PROJECTS

INSTITUTION	PROJECT MANAGER	TITLE
Altas Corporation	Francis de Winter	Overview of National Solar Energy R&D Programs of Many Nations
Altas Corporation	Francis de Winter	Workshop on Use of Solar Energy for Cooling Buildings
Argonne National Laboratory	Martin Kyle	Program Support for the Research and Development Branch – Thermal Energy Storage
Brookhaven National Lab.	J. Gary Cottingham	Program Support for the Research and Development Branch – Solar Heat Pumps and Cooling
Kaman Science Corporation	Douglas M. Jardine	CCMS Report on Phoenix Project
Lawrence Berkeley Laboratory	Michael Wahlig	Program Support for the Research and Development Branch – Controls and Non-Engineering Aspects
Los Alamos Scientific Lab.	J.D. Balcomb	Program Support for the Research and Development Branch – Collectors
Los Alamos Scientific Lab.	J.D. Balcomb	Workshop on Passive Solar Heating and Cooling of Buildings
Los Alamos Scientific Lab.	J.D. Balcomb	Assistance in Developing Solar Heating and Cooling R&D Plan
Univ. of Maryland	Redfield Allen	Assist the NATO Committee on the Challenges of Modern Society (CCMS) Solar Heating and Cooling of Buildings Project
National Bureau of Standards	Elmer Streed	Assist Division of Solar Energy in Planning for IEA Cooperative Projects
Pennsylvania State Univ.	Stanley F. Gilman	Workshop on Heat Pumps for Assisting Solar Energy Systems
Sandia Laboratories	Sam Varnado	Program Support for the Research and Development Branch – Systems

Table 2

PATH DESCRIPTIONS FOR HEATING AND COOLING OF BUILDINGS

APPLICATION	PATH DESCRIPTION
Service Hot Water	Liquid-Heating Collectors Air-Heating Collectors
Space Heating	Solar-Assisted Heat Pump Direct Solar Heating of Space or Structure Air-Heating Collectors Liquid-Heating Collectors
Space Cooling	Concentrating Collectors with Absorption or Rankine Cycle Chiller Advance Non-Concentrating Collectors with Absorption or Rankine Cycle Chiller Flat Plate Collectors with Desiccant Chiller Evaporative and Night-Effect Cooling

DEVELOPMENT FOR BUILDING DEMONSTRATION PROGRAM

One of the objectives of the development for building demonstration program is to develop cost-effective, reliable, and acceptable solar heating and cooling subsystems and systems that are mass-producible and marketable by industry. The program utilizes both available technology and technology advances resulting from the Research and Development programs to bring solar energy systems to the point of residential and commercial application for test and evaluation in the demonstration programs.

The need for this effort is based on the fact that solar heating and cooling technology is at various levels of design maturity and that a concentrated development effort is required in selected areas to bring solar systems to the market place. The companion Research and Development program is structured to provide a continuing advancement of the technological base to ensure the latest research innovations.

As subsystems and systems complete the development process, they will be referred to the appropriate demonstration activity for evaluation and qualification testing. If found acceptable they will be included in demonstration projects. This element of the demonstration program is being implemented and managed by the NASA Marshall Space Flight Center. Five Requests for Proposals (RFP) were released in October 1975 spanning a range of systems and subsystems where additional development is needed. Multiple contracts have been awarded in each category of the RFP's and the total expenditure of funds over the life of the development in support of demonstration programs is expected to be in the neighborhood of $40M. Each of the contracts initiated under this part of the program are briefly described in ERDA 76-128 (4).

Another objective of the development for building demonstration program is to collect, evaluate, and disseminate the resulting demonstration information to all potential users. This objective is being pursued through: establishment of data requirements; development of effective collection methods; standardization of evaluation procedures; establishment of methods for storing and ready retrieval of information; and development and implementation of effective information dissemination techniques.

A centralized data collection and evaluation scheme has been selected (and is being implemented) as the most cost-effective way to handle the wide range and volume of both instrumented and "soft" data that will be developed in the National Solar Heating and Cooling Demonstration Program. Data flows from selected demonstration projects through an instrumentation package which transmits the data by conventional telephone lines into a central processing facility where the data is analyzed and subsequently stored in a computer-compatible form in a data base or in a final report from in the data bank. The information is then made readily available to the user either as a result of direct request to the data bank or with the assistance of data dissemination contractors. The non-instrumented (or "soft") data, gathered and prepared by the demonstration contractors, is also stored in a data base and the data bank from which the users may acquire these data.

The third objective of the development for building demonstration program is the development and adaptation of standards which reflect the proper degree of technological advancement which the industry is willing to and can support in the marketplace.

Definitive performance criteria and standards will define the limits within which an industry can develop and flourish. The data collected from the demonstration program will provide a sound basis for the consensus standards process to function. To date three major steps have been made in this area:

- Interim Performance Criteria have been published (5).
- Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems have been published for review and comment (6).
- Plan for the Development and Implementation of Standards for the Solar Heating and Cooling Applications has been developed (7).

This last item is an important step because the plan has been developed in conjunction with the American National Standards Institute Steering Committee on Solar Energy Standards Development. The projects presently underway in the standards and criteria development area are briefly summarized in ERDA 76-128 (4).

RESIDENTIAL BUILDINGS DEMONSTRATION PROGRAM

The residential buildings demonstration program has two major elements:

- The Department of Housing and Urban Development Request for Grant Application (RFGA).
- Department of Defense (DOD) Residential Demonstration Projects.

Hud Demonstrations

The first large-scale test of solar energy in housing was inititated by HUD in January of 1976. Approximately 55 grants were awarded from a field of 250 applicants which included private builders, public agencies, and universities. Each of the dwelling units – 102 single-family and 41 multi-family, including three student residences – will be equipped with a commercially available unit designed and integrated for a specific purpose of providing either heating and/or hot water. All these projects will be operational this year. Each project is briefly described in ERDA 76-127 (8).

DOD Demonstrations

Concurrent with demonstrations in the private sector a program of demonstration was initiated in the Federal housing sector. Fifteen sites were selected by the DOD to provide solar heating and hot water to 50 housing units. The projects will encompass both new construction and retrofit applications. Each project is briefly described in ERDA 76-127 (8). All of these projects are under construction with completion expected this year.

COMMERCIAL BUILDINGS DEMONSTRATION PROGRAM

The first early "experiments" were initiated by the National Science Foundation (NSF) applying solar energy to four schools in Minneapolis, Minn.; Boston, Mass.; Timonium, Md.; and Warrenton, Va.* Based upon these early experiences and the establishment of ERDA, an additional 26 projects have been initiated in the Federal and private sectors. The first major solicitation which initiated the first cycle of the Commercial buildings demonstrations was the Program Opportunity Notice (PON) in the fall of 1975.

The PON solicited projects for the application of solar energy to commercial size buildings. The solicitation required a total team capability to integrate solar equipment into a building (new or existing) utilizing available technology. *Table 3* summarizes the response.

The salient features of the PON were that an overwhelming interest was displayed (308 proposals), cost sharing was emphasized and achieved, and a balance between new and retrofit applications which included a wide geographic/climatic spread and several building types was possible. A good distribution in terms of heating, hot water and combined heating and cooling was made possible due to the wide ranging response. The projects are currently underway with varying project completion dates of 3 to 15 months. The next cycle of the Commercial Demonstration Program was initiated in the fall of 1976 with a wide range of applications and opportunities envisioned.

In addition to these projects in the public and private sector, several projects have been initiated with the various Federal agencies to establish actual construction and operation experience with solar equipment.

All of these commercial demonstration projects are briefly described in ERDA 76-127 (8).

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*Special Format Reports have been prepared on three of these projects.

Table 3

SUMMARY OF PON RESULTS

PROPOSALS RECEIVED	308
PROPOSALS SELECTED	34 in 23 states
TOTAL PROJECT COSTS	$9.6M
ERDA FUNDS PROVIDED	$7.5M (78%)
PRIVATE SECTOR PROJECTS	20
ERDA FUNDS	$3.7M
PUBLIC SECTOR PROJECTS	14
ERDA FUNDS	$3.8M
SOLAR ENERGY APPLICATIONS	
HEATING	8
HOT WATER	6
HEATING AND HOT WATER	10
HEATING AND COOLING	5
HEATING, COOLING, HOT WATER	4
COOLING	1
TOTAL	34
COMMERCIAL OFFICE BUILDINGS	8
CITY OR STATE OFFICE BUILDINGS	2
SCHOOL BUILDINGS	8
INDUSTRIAL BUILDINGS	6
HOTELS AND MOTELS	3
MEDICAL CENTERS	2
FIRE HOUSES	2
SPECIAL PURPOSE PUBLIC BUILDINGS	2
LIBRARY	1
TOTAL	34

AGRICULTURAL AND INDUSTRIAL PROCESS DEMONSTRATIONS

The Agricultural and Industrial Process Heat Program is divided into the two obvious parts: Agricultural Applications and Industrial Process Applications. Responsibility for the management of the agricultural aspects of the program has been delegated to the U.S. Department of Agriculture, with monitoring of progess by ERDA personnel.

The USDA, through its Agricultural Research Service (ARS) is working in coordination with State Agricultural Experiment Stations. ARS laboratories, universities and industry in conducting experiments and demonstrations in:

- Solar Grain Drying
- Agricultural Food Processing
- Solar Crop Drying
- Solar Heating of Greenhouses
- Solar Heating of Animal Shelters

The Agricultural and Industrial Process Heat Branch is working with ERDA laboratories and industry in the development of solar heat energy applications to industrial processes in three areas:

- Low temperature applications, below the boiling point of water, 212° F (100° C);
- Intermediate temperatures, from the boiling point of water to about 350° F (176° C); and,
- High temperature applications, above 350° F (176° C).

In the early stages of the program, for both industry and agriculture, priority is being given to the application of those system designs that are based on state of the art components, instead of components requiring significant research and development effort. The substantial Federal expenditures in solar system components, in this and other programs, will allow the near-term application of solar energy to more diverse agricultural and industrial processes than would otherwise occur. It will also accelerate systems development and industry acceptance of solar energy technology as a viable means of substituting solar heat for that which is generated by combustion of fossil fuels.

The agricultural applications portion of the program has initially built up at a more rapid rate than the industrial process heat applications. The planning, however, calls for a crossover in the relative emphasis on the two portions of the program during 1976 and 1977. The industrial process heat portion of the program will grow to almost ten times the size of the agricultural portion by 1980 because of the great potential for solar energy applications in many types of industrial operations.

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(5) *Interim Performance Criteria for Solar Heating and Cooling and Combined Heating/Cooling Systems and Dwellings*, Energy Research and Development Administration, Division of Solar Energy.

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ACTIVITIES OF THE EUROPEAN COMMISSION IN THE FIELD OF SOLAR HEATING AND COOLING*

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INTRODUCTION

Four years ago the European Commission established an R&D programme on solar energy. For the short and medium term, the most promising field seems to be the solar heating and cooling of buildings. The programme of the Commission can be divided into two parts:

- Direct action which consists of specific studies carried out at the Joint Research Center (JRC) at Ispra, Italy.
- Indirect action consisting of national activities, partially financed by the Commission.

In the field of solar heating and cooling of buildings, the efforts have been focussed on the following points:

- Technology
- Standard test procedures for solar collectors
- System Studies
- Dissemination of information

TECHNOLOGY

It is felt that the main effort concerning the development of solar components should be carried out by industry and that the JRC should intervene only in specified areas of competence, such as thermal testing, surface metallurgy, etc. In the framework of collaboration with industry and national insistutes, the JRC has carried out studies on different types of "high performance collectors" based on the following principles:

- Honeycomb sturctures
- Selective surfaces
- Corrugated geometry
- Partial vacuum

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*The EC participated in the Copenhagen meeting as an observer. While this is not a report on a national program per se, it was believed that the inclusion of a report on the significant solar heating and cooling activities of the FC would be appropriate and informative.

In the field of thermal storage, the main effort has been carried out through indirect action. Eight research contracts were signed with European national or industrial laboratories concerning applications based on:

- Stratification of water
- Latent heat of fusion of hydrate salts, paraffine, etc.,
- Chemical reactions

STANDARD TEST PROCEDURES

Due to European climates, some alternative test procedures to the NBS methods have been investigated. These procedures allow outdoor transient and indoor methods for the determination of the heat losses and the $(\alpha\tau)_e$ by simulators. For this purpose a round-robin test programme with the participation of 19 European laboratories has been undertaken with 3 different types of collectors.

SYSTEM STUDIES

At the JRC, a laboratory for the study of solar systems (SSL) is in operation. The aim of the laboratory is:

- Performance and endurance tests of components
- Performance tests of complete systems
- Confrontation of experiemental data with mathematical models.

Various heating systems are installed, including heat pumps assisted by solar systems and an absorption machine for refrigeration.

DISSEMINATION OF INFORMATION

An important aspect of the activity of the JRC will be the promotion of the use of solar energy. Besides the demonstration impact of the JRC-installations, a programme of courses and meetings on the subject is in preparation. Training courses for students and graduates will be made available.

IV. SUMMARIES OF THE 1976 SPECIAL FORMAT REPORTS

INTRODUCTION

Inasmuch as the CCMS Solar Energy Pilot Study is based on information exchange, it is essential that a considerable portion of this exchange consist of standardized reports which provide detailed design and performance data on operating solar systems. With such standardized reports, each participating country can effectively utilize the performance results of those reported projects which are relevant to their own programs and projects. This is the purpose of the Special Format Reports which have been prepared and distributed by several countries during 1976 and represent the first exchange of these reports. Summaries of the reports are found in this section of the annual report. Details of the System Reporting Format–which serves as the guide for preparation of these reports–may be found in Appendix G.

SUMMARY

During the year preceeding the 1976 CCMS meeting in Copenhagen, several countries prepared Special Format Reports and Preliminary Special Format Reports describing the performance or projected performance of solar heating systems, solar cooling systems, passively solar heated dwellings, and solar heated low energy dwellings. The summary reports, presented at the Copenhagen meeting in a special summary session, are listed in *Table 1*. The summary reports, given on the pages following *Table 1*, give the principal features of the Special Format Reports prepared by representatives of the various countries. The reports themselves are being introduced into the CCMS information system as they become available.

Australian progress in obtaining performance data on three domestic hot water systems operating, to date, at system solar efficiencies of up to 25% is reported. A Canadian interim format report summarizes the status of an annual solar heat storage system and a combined solar heating and heat pump system. The performance of the Zero Energy House is described in the Danish Special Format Report. A 30,000 liter hot water storage tank operates seasonally between a maximum of 85°C and a minimum of 43°C.

The status of Special Format Report projects in heat pipes and solar tap water heating is described in the Federal Republic of Germany summary. The summary report of France concerns the thermal performance of the glazed solar heated masonry walls (Trombe wall) in an experimental dwelling at Odeillo. A subsystem report covering the performance of a reflecting horizontal collector is presented by Greece. Sweden in its report summarizes the performance, or projected performance, of three dwellings. A solar heating dwelling system with hot water storage and floor slab storage is capable of operating down to a minimum water temperature of 28°C. The second dwelling contains a water-to-air solar heating system with 0.4 m^3 of water storage per m^2 of collector and an inert-gas drain-down system to prevent freezing. The third dwelling is designed with passive solar-heating features and low-energy losses. The United States summary of Special Format Reports covers the performance of seven systems, including two solar heated schools, one solar heated and cooled school, a solar heated and cooled residence, a combined solar heating and heat pump residential system, an apartment domestic hot water system, and a large shallow solar pond for supplying industrial process hot water.

Table 1

SYSTEM PROJECTS REPORTED IN 1976 SPECIAL FORMAT REPORTS

COUNTRY	PROJECT
AUSTRALIA	Progress Report on the Performance of Three Australian Solar Hot Water Systems.
CANADA	Special Format Report (Interim) on the Provident Solar House, Toronto, Ontario.
	Special Format Report (Interim) on the Mississauga Solar House, Toronto, Ontario.
DENMARK	Special Format Report on the Zero Energy House, Technical University of Denmark, Lyngby, Denmark.
FEDERAL REPUBLIC OF GERMANY	Adaption of Solar Heat Pipes as Absorbers for a House Heating System in Middle Europe.
	Solar Tap Water Heating Project.
FRANCE	Experimentation with Solar Heated Houses at Odeillo.
GREECE	Reflecting Horizontal Solar Collector (Interim Report).
SWEDEN	Report on the Euroc AB Solar Energy Building in Limhamn - The "Termoroc" House.
	Report on the AB Ostgotabyggen Solar Energy Building in Linköping.
	Report on the STR Solar Energy Building in Vetlanda.
USA	Performance of the Sohio Solar Water Heating System Using Large Area Plastic Collectors.
	Report of the Phoenix Corporation-City of Colorado Springs Solar Heating Project.
	Design, Construction, and Testing of the Colorado State University Solar House I Heating and Cooling System.
	Northview Junior High Solar Energy School Heating Augmentation Experiment.
	Report of the George A. Towns Elementary School Solar Heating and Cooling Project, Atlanta, Georgia.
	Report on the Grover Cleveland School Solar Heating System.
	Project Sage Solar Assisted Gas Energy Project.

AUSTRALIA: SUMMARY OF 1976 SPECIAL FORMAT REPORTS

R.N. Morse
Commonwealth Scientific and Industrial Research Organization
Solar Energy Studies

PROGRESS REPORT ON THE PERFORMANCE OF THREE AUSTRALIAN SOLAR HOT WATER SYSTEMS

The projects covered by the 1976 special format report involve three commercial installations supplying service hot water to buildings, one of which has been operating since 1962, another since 1966, and the third since 1975. They vary in size from 60 m^2 of collector with 4,1000 litre storage to 10 m^2 with 1,050 litre storage. In every case, supplementary heating is provided. One employs off-peak electricity, another continuous electricity, and the other oil heating. One is a residential school, another a plant research laboratory, and the third a yacht club, and all have been operating normally except that instrumentation has been added to measure incident radiation, total water consumption, amount of supplementary heating, the ambient temperature and wind velocity. The report is a Progress Report since it only covers a portion of the year, and the observations will be continued next year and a final report presented.

At this stage, it appears that the annual solar contribution varies from 45% to 66%, and the system solar efficiency between 21 and 25%. All systems are performing satisfactorily in that they are capable of supplying hot water at the temperature required when needed.

Arising from the preparation of these reports, it appears that some modification to the format would be desirable. In the first instance, we would propose a summary of not more than five pages containing schematic lay-outs, photographs and conclusions, together with summarized performance figures in the form of tabulated weekly totals. The data should include weekly values of the system load showing how calculated, the solar contribution showing how calculated, and the solar radiation incident on the collectors. In addition, we would proposed annual totals for all these as well as the monetary value of the solar contribution in the terms of the value of the fuel saved. *Table 1* (from the special format report) will illustrate this.

Table 1

SOMERS YACHT CLUB DATA

WEEK	HOT WATER CONSUMPTION VOLUME ENERGY (kl)	ENERGY IN HOT WATER H (MJ)	ELECTRICITY CONSUMPTION E (MJ)	ELEC. ENERGY CONVERTED TO HOT WATER 0·7E (MJ)	SOLAR CONTRIBUTION H-0·7E (MJ)	SOLAR CONTRIBUTION (%)	SOLAR RADIATION ON COLLECTORS (MJ)	SYSTEM SOLAR EFF. (%)	WIND (km)
28/12-4/1	9·370	1177	270	189	988	84	2085	47	2242
4/1-11/1	6·540	849	286	200	649	76	2026	32	3015
11/1-18/1	9·415	1301	260	182	1119	86	2059	54	2214
18/1-25/1	12·383	1400	333	233	1167	83	2130	55	3533
25/1-1/2	4·394	644	217	152	492	76	1602	31	2750
1/2-8/2	2·787	502	96	67	435	87	2156	20	2477
8/2-15/2	2·220	335	116	81	253	76	2076	12	4211
15/2-22/2	2·476	404	186	130	274	68	1688	16	580
22/2-29/2	1·904	263	142	99	164	62	1531	11	1817
29/2-7/3	5·036	632	391	274	358	57	1611	22	3175
7/3-14/3	4·885	675	354	248	427	63	1637	26	1949
14/3-21/3	0·229	38	142	99	-	-	1494	-	2048
21/3-28/3	0·593	94	183	128	-	-	1153	-	1686
28/3-4/4	1·488	230	186	130	100	43	1337	7	1987
4/4-11/4	0·125	22	170	119	-	-	1235	-	1793
11/4-18/4	2·637	353	184	129	224	63	1080	21	1312
18/4-25/4	1·990	350	264	185	165	47	982	17	7119
TOTAL	68·472	9269	3780		6815	74	27882	24	43908

CANADA: SUMMARY OF 1976 SPECIAL FORMAT REPORTS

J.R. Sasaki
Division of Building Research
National Research Council of Canada

At the 1975 Palo Alto Meeting, the National Research Council expected to prepare special format reports on three solar demonstration houses that were under construction. Two of these houses, the Mississauga House and the Provident House, are now completed and the solar heating systems are operational. Interim format reports on the features, but not the performance, of the two houses were sent to the CCMS contact persons; complete format reports will be prepared in 1977.

The third house, Gananoque House, does not yet have an operational solar heating system and it now appears unlikely that anything more than a data sheet will be prepared for this house.

PROVIDENT SOLAR HOUSE – TORONTO, ONTARIO

I. GENERAL DESCRIPTION OF PROJECT

A. **Project Objectives:** To demonstrate the technical feasibility of utilizing a solar heating system with seasonal heat storage to satisfy 100% of the space heating demand of a house under Canadian climatic conditions. The system is to be operational during the summer of 1976. The thermal performance of the system is to be monitored from the fall of 1976 for one full year. The house and solar heating system were designed by Messrs. F.C. Hooper and J. Hix of:

Envirogetics, Ltd.
207 Queen's Quay West
Toronto, Ontario, Canada

B. **Description of Environment**

1. **Climate:** Toronto, Ontario – Trewartha classification - DBF (humid; continental; cool summers; even distribution of precipitation throughout year).

2. **Location of Solar House:** Latitude = 44°N
Longitude = 79° 35′ W
Altitude = 295 meters

House is located in a rural housing development in King Township near Toronto, 40 km north of Lake Ontario. The area is hilly but there are no mountains within a radius of 500 km. The air is clear of industrial pollution.

3. **Solar Radiation:** See *Table 1* for values of the monthly-mean, daily total and diffuse insolation on a horizontal surface for Toronto during 1970 to 1972.

C. Description of System

The house consists of three parts: the garage, the conservatory, and the living space. The living space consists of two floors, 248 m^2 in total area. Windows are triple-glazed; the walls contain 15 cm of fiberglass insulation; and the roof contains 30 cm of figerglass insulation. An earth berm covers the north wall of the house. The house has two separate solar heating systems: one for heating the living space and another for heating the service (domestic) water.

1. **Space Heating System** *(Fig. 1)*: The system consists of $66.7 m^2$ of flat plate collectors, and a seasonal heat storage tank of approximately 274 m^3 located beneath the living space.

   Orientation: The collector array is oriented due south and the collector inclination angle (angle between the collector normal and horizontal) is 37.5^o.

   Operation: Solar heat is collected throughout the year and is terminated only when useful engergy cannot be collected for space heating or for addition to storage. Collection also terminates when the storage temperature reaches 84^oC. Under freezing conditions, the water in the collectors is drained to storage when solar heat is not being collected.

   Heating: The water-to-air heat exchanger in the space heating, air distribution circuit is sized to satisfy the design heating load with a water temperature of 34^oC.

2. **Service Water Heating System**

   The system consists of 7.4 m^2 of flat plate collectors, a heat exchanger, a 0.45 m^3 holding tank, and a 0.14 m^3 service water heating tank containing a 3 kW electric heater. The collection circuit contains a 100 percent anti-freeze solution for freezing protection. The collector bearing and inclination are identical to that for the collectors of the space heating system.

II. SYSTEM THERMAL PERFORMANCE

A. Daily, Monthly and Annual Values of the Mean Daily

1. **Total Energy Required**

   House space heating load (design) = $190 \frac{W}{^oC}$ or $4.56 \frac{kWh}{^oC\text{-day}}$

2. **Supplementary Energy Required**

   Anticipate no supplementary energy required for space heating. Anticipate 25% of service water heating demand to be met with electrical energy.

3. Solar energy incident on collector; solar energy collected; solar energy used – unavailable.

B, C, D & E – Unavailable.

III. SYSTEM ECONOMIC ANALYSIS – Unavailable

IV. FORMAT FOR REPORTING SUB-SYSTEM PERFORMANCE

A. Solar Collector

1. Physical description

a. Collectors for Space Heating System:

Total area = 66.7 m^2
Number = 44 modules
Cover = single sheet of low-iron glass
Absorber & tubes = steel, with selective assorber coating
Insulation = 3.8 cm of figerglass insulation

b. Collectors for Service Water Heating System

Total area = 7.4 m^2
Number = 6 modules
Cover = single sheet of low-iron glass
Absorber & tubes = copper, with selective absorber coating
Insulation = 6.3 cm of fiberglass insulation

2. **Thermal Performance** – Unavailable

3. **Lifetime Performance Characteristics** – Unavailable

B. **Heat Transfer Sub-Systems** – See *Figure 1.*

C. **Thermal Energy Storage Sub-System** (Space Heating System)

Volume of storage = 274 m^3
Tank dimensions = 8.5 m (wide) x 8.5 m (long) x 5.5 m (deep)
Insulation – walls = 10 cm foam polyurethane (sprayed)
– floor = 15 cm foam polyurethane (sprayed)
-- cover = 30.5 cm figerglass insulation
Minimum storage water temperature = 33°C
Maximum storage water temperature = 84°C

D. **Air Conditioning Sub-System** – Not Applicable

Table 1

MONTHLY MEAN DAILY INSOLATION ON HORIZONTAL SURFACE (MJ/m² day) TORONTO – 1970 to 1972

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1970												
TOTAL	6.4	10.2	14.9	18.8	17.7	23.0	20.2	19.7	13.3	6.6	4.3	4.2
DIFFUSE	3.9	–	–	–	9.7	10.7	10.1	–	6.0	3.6	2.7	2.6
1971												
TOTAL	–	7.2	12.9	16.7	21.1	22.7	21.1	20.1	12.1	8.7	4.7	3.5
DIFFUSE	–	5.1	7.1	7.1	7.7	9.4	8.0	7.4	6.5	4.5	3.0	2.2
1972												
TOTAL	5.7	9.4	14.1	17.9	21.4	18.8	21.0	17.4	13.8	8.0	3.9	3.0
DIFFUSE	3.5	5.9	7.5	7.5	7.7	10.2	9.9	7.6	6.2	4.5	2.8	2.3

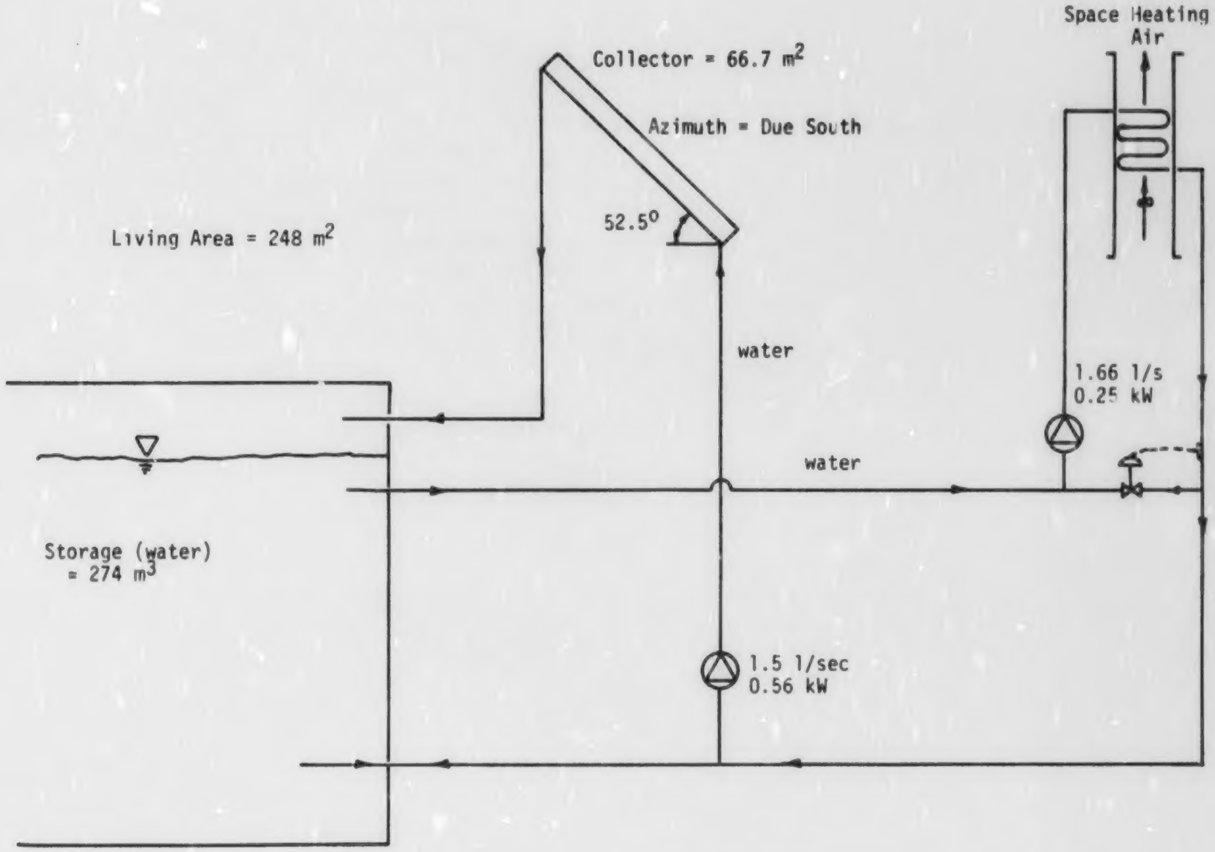

Space Heating Air
Collector = 66.7 m²
Azimuth = Due South
52.5°
Living Area = 248 m²
water
1.66 l/s
0.25 kW
water
Storage (water) = 274 m³
1.5 l/sec
0.56 kW

Figure 1. Solar Space Heating System – Provident House, Toronto

MISSISSAUGA SOLAR HOUSE – TORONTO, ONTARIO

I. GENERAL DESCRIPTION OF PROJECT

A. **Project Objectives:** To demonstrate the technical feasibility of utilizing a solar heating system in association with an electric heat pump to satisfy a significant portion of the space heating demand of a house under Canadian climatic conditions. The system has been in operation since February 1976 and its thermal performance will be fully monitored in the fall of 1976 for one full year. The principals responsible for the project were Messrs. D. Lorriman, D. Lee, and B. Fergusson of:

Mississauga Solar Demonstration Project, Ltd.
207 Queen's Quay West
Toronto, Ontario, Canada

B. Description of Environment

1. **Climate:** Toronto, Ontario – Trewartha classification – DBF (humid, continental, cool summer, even distribution of precipitation throughout year).

2. **Location of Solar House :**

   Latitude = $43^{\circ}\ 30'$ N
   Longitude = $79^{\circ}\ 55'$ W
   Altitude = 180 meters

   House is located in a suburban housing development in the town of Mississauga near Toronto, 16 km north of Lake Ontario. The area is flat, and the air is fairly clear of industrial pollution.

3. **Solar Radiation:** See *Table 1* in previous Provident House report for values of the monthly-mean, daily total and diffuse insolation on a horizontal surface for Toronto, 1970 to 1972.

C. Description of House and System

The house has two living floors, 135 m^2 in total area. Windows and sliding glass doors are double-glazed; the walls contain either 7.6 cm of polystyrene board insulation or 15 cm of fiberglass insulation, and the ceiling contains 20 cm of fiberglass insulation.

The solar heating system *(Figure 2)* consists of 64.4 m^2 (gross) of flat plate collectors, and two water storage tanks totalling 18 m^3 located in the basement. Water is the heat transport medium for both the collection circuit and the heat distribution circuit. The system is intended to satisfy approximately 60% of the space heating demand.

1. **Orientation:** The collector array faces due south and the collector inclination (angle between the collector normal and horzontal) is 30°.

2. **Operation:** Solar heat is collected whenever heat can be added to either of the two heat storage tanks. The collector array is drained to storage when solar heat is not being collected.

3. **Heating:** Whenever the temperature of the water from storage is greater than 46°C, it passes directly to a water-to-air heat exchanger in the space heating air distribution circuit. The heat exchanger is sized to satisfy the design heating load with water at 46°C. Service water preheating is achieved by drawing water from storage through the preheating tank.

II. SYSTEM THERMAL PERFORMANCE

A. Daily, Monthly, and Annual Values of the Mean Daily

1. **Total Energy Required**

Space heating load (design) = $361 \frac{\text{W}}{^{\circ}\text{C}}$ or $8.66 \frac{\text{kWh}}{^{\circ}\text{C-day}}$

2. **Supplementary Heat Required**

Anticipate 30 to 40% of total space and service water heating demand to be satisfied by electrical energy.

3. Solar energy incident, collected, used -- Unavailable

B, C, D, & E – Unavailable

III. SYSTEM ECONOMIC ANALYSIS – Unavailable

IV. FORMAT FOR REPORTING SUB-SYSTEM PERFORMANCE

A. Solar Collectors

1. **Physical Description**

Total area (gross) = 64.4 m^2
Number = 33 modules
Cover = single sheet of low-iron glass
Absorber & tubes = copper, with selective absorber coating
Insulation = 6.3 cm figerglass insulation

2. **Thermal Performance** – Incomplete data from manufacturer

3. **Lifetime Performance Characteristics** – Unavailable

B. Heat Transfer Sub-System – See *Figure 2*

1. Solar heat exchanger – 4 row water coil with capacity to raise o.5$\frac{\text{m}^3}{\text{s}}$ of air from 24°C to 43.3°C, with 0.64 ℓ/s of water entering at 49°C.

2. Heat pump (water-to-air) – 15 kW heating capacity, with 0.5 $\frac{\text{m}^3}{\text{s}}$ of air entering at 24°C and 0.64 ℓ/s of water entering at 15.5°C.

3. Supplementary electrical space heater — 10kW heating capacity.

4. Service water electrical heater - 4.5 kW heating capacity.

C. **Thermal Energy Storage Sub-System**

Two concrete tanks:
Dimensions of each tank = 2.76 m x 1.13 m x 2.74 m deep
Total volume of water in two tanks = 18 m^3
Insulation of tanks = 10 cm polyurethane around all sides, plus 7.6 cm polystyrene boards adjacent to exterior wall. 10 cm fiberglass insulation plus 7.6 cm polystyrene board on top.
Maximum storage water temperature = not available.
Minimum storage water temperature = not available.

D. **Air Conditioning Sub-System**

The heat pump described in B.2 can be operated in the reverse direction to provide space cooling, by using main water at approximately 7°C as the heat sink.

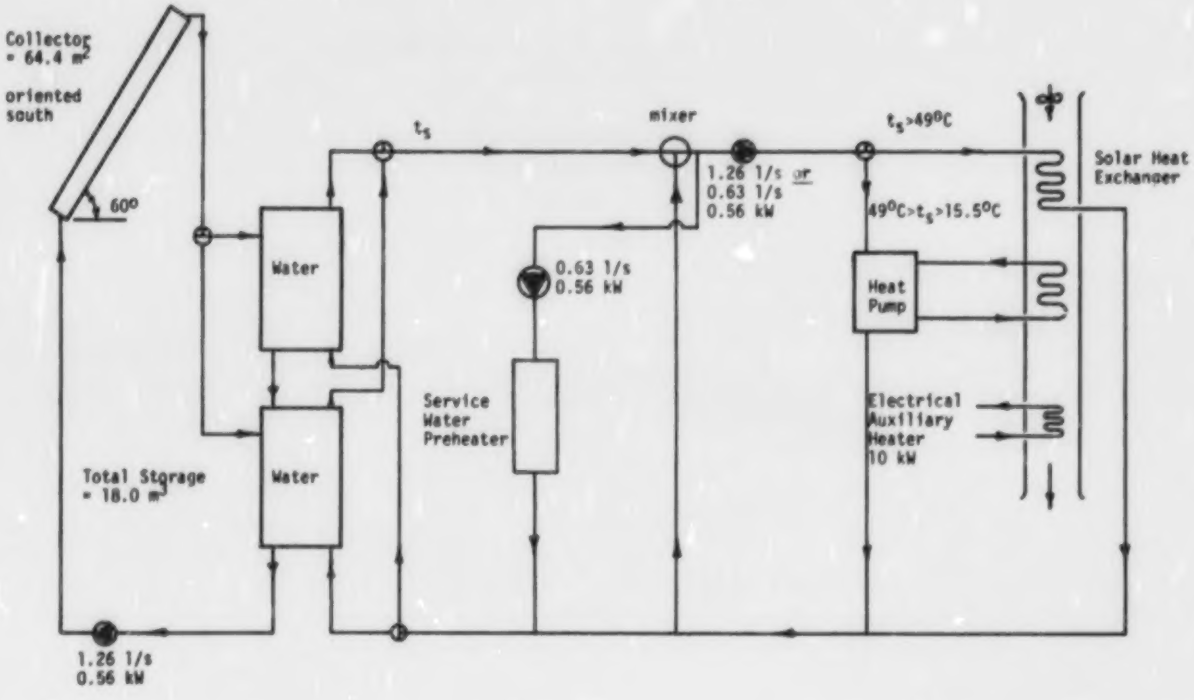

Collector = 64.4 m^2
oriented south
60°
Total Storage = 18.0 m^3
Water
Water
1.26 l/s
0.56 kW
t_s
mixer
1.26 l/s or
0.63 l/s
0.56 kW
0.63 l/s
0.56 kW
Service Water Preheater
t_s>49°C
49°C>t_s>15.5°C
Heat Pump
Electrical Auxiliary Heater 10 kW
Solar Heat Exchanger

Figure 2. Mississauga Solar House, Toronto, Ontario, Canada
Living Area = 135 m^2

DENMARK: SUMMARY OF 1976 SPECIAL FORMAT REPORT

Torben V. Esbensen and Svend Aa. Svendsen
Thermal Insulation Laboratory
Technical University of Denmark

THE ZERO ENERGY HOUSE
TECHNICAL UNIVERSITY OF DENMARK, LYNGBY

I. GENERAL DESCRIPTION OF PROJECT

A. Objective of Project

To construct a single-family house by use of energy conservation equipment in such a way that in essentials the house can be heated all winter by the energy supply from persons, electric lighting, cooking, TV, etc.

To demonstrate the technical feasibility of utilizing a solar heating system with seasonal heat storage to satisfy 100 per cent of the necessary additional heat supply, including energy for hot water supply, under Danish climatic conditions.

The house has been in operation since April 1975. The thermal performance of the system has been monitored since January 1976.

The planning and construction of the experimental house is the result of a team work between three institutes of the Technical University of Denmark: The Thermal Insulation Laboratory, the Institute of Building Design, and the Heating and Air Conditioning Laboratory.

B. Description of the Environment

1. Climate

Annual rain fall: 500mm per year.

Average daily sunny hours: 4.3.

Annual average cloud cover fraction: 0.61.

2. Location of the Zero Energy House

Latitude: 55° 47′ north.

Longitude: 12° 31′ east.

The house is located on the experimental field of the Technical University. The area is flat, there are no solar obstructions, the air is clear of industrial pollution.

3. Solar Radiation

Mean yearly global insolation measured hourly on a horizontal surface in the period 1959–69: 2.8kWh/m^2 day.

Mean yearly diffuse insolation measured hourly on a horizontal surface in the period 1966–69: 1.3kWh/m^2 day.

4. Ambient Temperatures

Mean yearly dry bulb temperature: 7.6 degrees Celsius.

Mean yearly relative humidity: 86 per cent.

Number of degree-days: 2900 (basis 17 degrees Celsius).

5. Wind

Average yearly wind speed: 5.2 m/s.

C. Description of System

1. Qualitative Description

The Zero Energy House is designed as two "living-boxes" of 60 sq m each, separated by a glass-roofed atrium of 70 sq m. A photograph of the house is shown in *Fig. 1*.

The walls are insulated with 30 and 40 cm of mineral wool. The windows are double-glazed with insulated shutters to increase the insulation value during the night.

The ventilating system is provided with an air-to-air heat recovery unit. Recovery degrees of about 85 per cent were measured in the laboratory. In the hot water system a water-to-water heat recovery unit is installed. The installation is calculated to have an average recovery degree of 50 per cent.

2. Quantitative Description

The solar energy system consists of 42 sq m of flat-plate solar collectors and a seasonal heat storage tank of 30 cu m buried in the ground just outside the house. The system is intended to satisfy 100 per cent of the heat requirement for space heating and hot water supply. A sketch of the principal features of the system is shown in *Fig. 2*.

Orientation. The collector is vertical and oriented due south.

Operation. Collection of solar heat takes place throughout the year and is terminated only when useful energy cannot be collected for addition to storage. The water in the collectors is drained to storage when solar heat is not being collected.

II. SYSTEM THERMAL PERFORMANCE

A. Annual Values of the Mean Daily

Calculated on the basis of the weather data in the Reference Year. Total energy required for space heating: 2300kWh per year. Total energy required for hot water supply: 2260kWh per year. No supplementary energy required for space heating and hot water supply is to be anticipated.

If the temperature in the storage tank drops below 43 degrees Celsius, automatically an electric heating element of 5kW will keep the temperature at 43 degrees Celsius.

Solar energy incident on collectors: 45000kWh per year.

Solar energy collected: 7330kWh per year.

Solar energy used: 4560kWh per year.

B, C, D, & E: Only available for the design period.

III. SYSTEM ECONOMIC ANALYSIS

Unavailable.

IV. FORMAT FOR REPORTING SUB SYSTEM PERFORMANCE

A. Solar Collectors

1. Description of Physical Configuration

A sketch showing the solar collector is given in *Fig. 3*. The solar collector consists of:

1. A thermopane made of two sheets of normal 5mm glass with an air space of 12mm.
2. A painted black absorber plate of two profiled steel plates, welded together in such a way that a serpentine channel is formed. The weight of the empty absorber plate is 14 kg/sq. m. and it contains 2.71 liter/sq. m water.
3. Backside insulation of 0.20m mineral wool and a cladding of plywood.

The solar collector is divided into four sections, each of them consisting of eight separate thermopanes and fourteen absorber plates which are connected in parallel. The total area of one section is of 11.0sq. m. The transparent area and the absorber area in one section is of 9.8sq. m.

2. Thermal Performance Characteristics

The efficiency has been measured since spring 1976. During most of the measuring period, the angle of incidence has been larger than 45 degrees, and the efficiency curve plotted in *Fig. 4* is therefore based on measurements taken when the angle of incidence was $i = 56^{\circ} \pm 2^{\circ}$. The efficiency for other values of "i" can be found by the aid of optical data as appears in *Fig. 5*.

B. Heat Transfer System

1. Description of Physical Configuration

A sketch showing the system is given in *Fig. 2.*

The working fluid is water with an inhibitor of Elementin added. At the same time this inhibitor softens the water to a hardness of a few degrees only.

The construction materials are unprepared steel pipes.

The solar system is a closed system under pressure so that any boiling can be avoided in the return pipe from the collector.

2. Thermal Performance Characteristics

There is a direct circulation of water between the storage tank and the collector.

The mass flow rate is of 0.4 litres/sec.

The data for the lifting pump in the system are 2.4cu m/h versus 12 x 10^4 N/sq. m head. Motor 365W.

The data for the smaller circulating pump are 2.0cu m/h versus 3.3 x 10^4 N/sq. m head. Motor 130W.

C. Thermal Energy Storage Sub-Systems

1. Description of Physical Configuration

A sketch showing the accumulator is given in *Fig. 6.*

Water is used as storage medium. The accumulator holds 30000 litres out of which about 1200 litres are reserved for the expansion of the water.

The tank is cylindrical and consists of unprepared steel plates. It is buried directly in the ground just outside the house. The tank is insulated with plates of stiff mineral wool. The thickness of the insulation is of min. 0.6 meters. On top of the insulation a foil of plastic is spread out.

Directly in the water for the solar system a 400 litre hot-water tank is placed. The cover of the tank has been leaking due to temperature changes. Therefore we must warn against bringing a similar system under pressure before the highest temperatures have been reached in the tank, and the bolts of the cover have been tightened once more.

2. Thermal Performance Characteristics

The temperature in the storage tank varies between 43 degrees Celsius and 85 degrees Celsius.

The mean temperature of the immediate surroundings is of about 15 degrees Celsius.

The heat loss is calculated to be of 5.8 W/$^{\circ}$C.

The yearly heat loss is of about 2800kWh, corresponding to 40 per cent of the solar energy collected.

Primarily due to the above-mentioned leak in the storage tank, the heat loss during last winter has been measured to be about 40 per cent higher than the calculated value.

D. Air-Conditioning Sub-System

Not applicable.

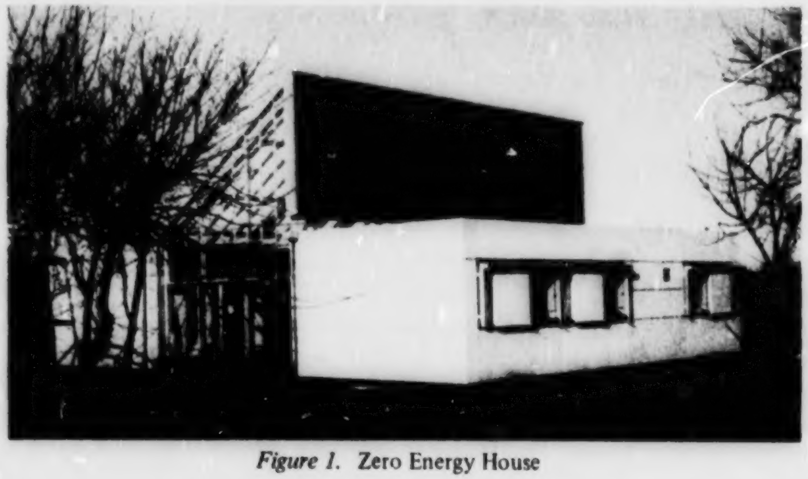


Figure 1. Zero Energy House

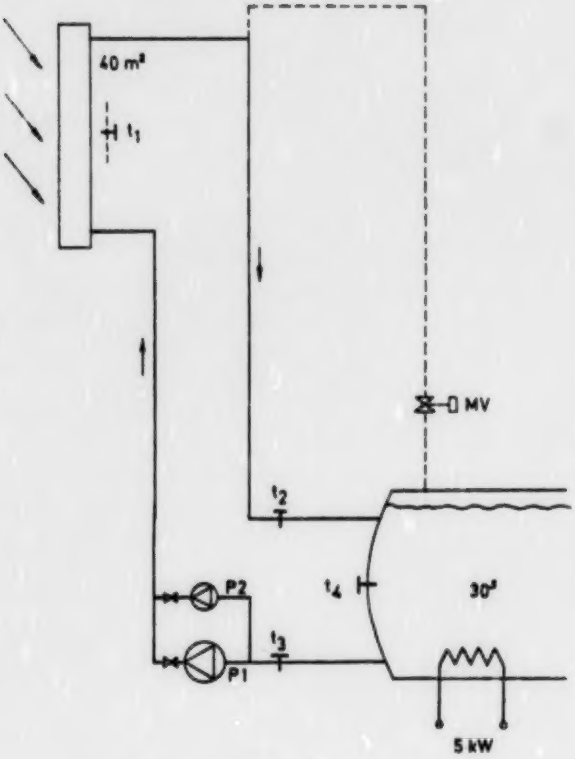


Figure 2. Sketch of the Solar Heating System

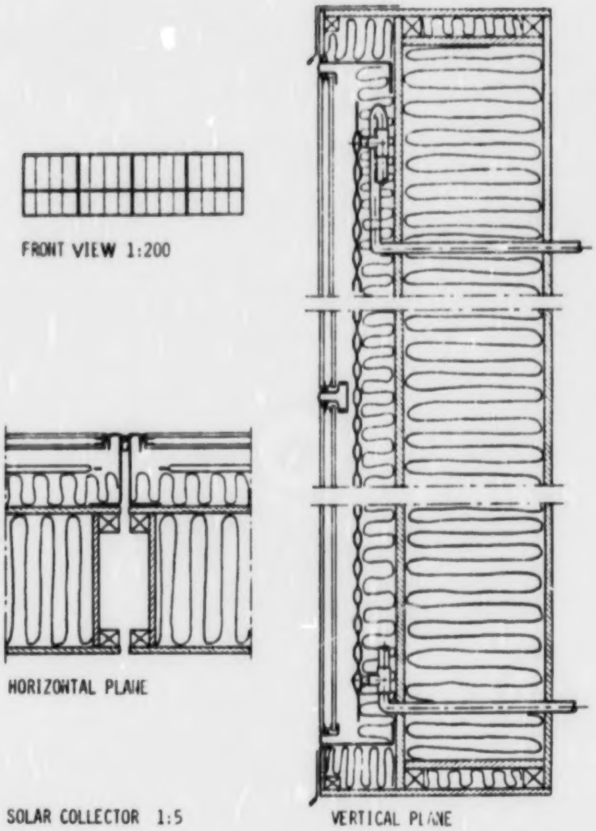
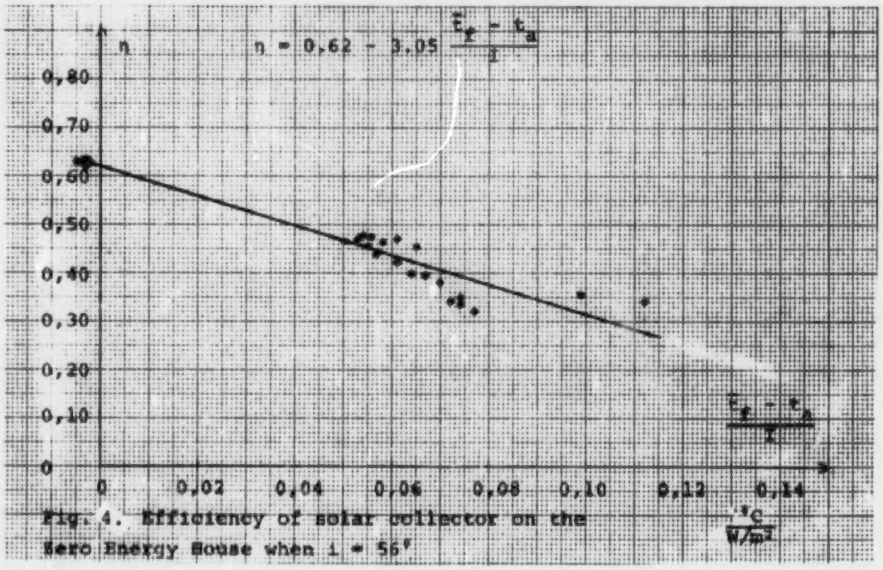

FRONT VIEW 1:200
HORIZONTAL PLANE
SOLAR COLLECTOR 1:5
VERTICAL PLANE

Figure 3. Sketch of the Solar Collector



$$\frac{^{\circ}C}{W/m^2}$$

Figure 4. Efficiency of solar collector on the Zero Energy House when i = 56°

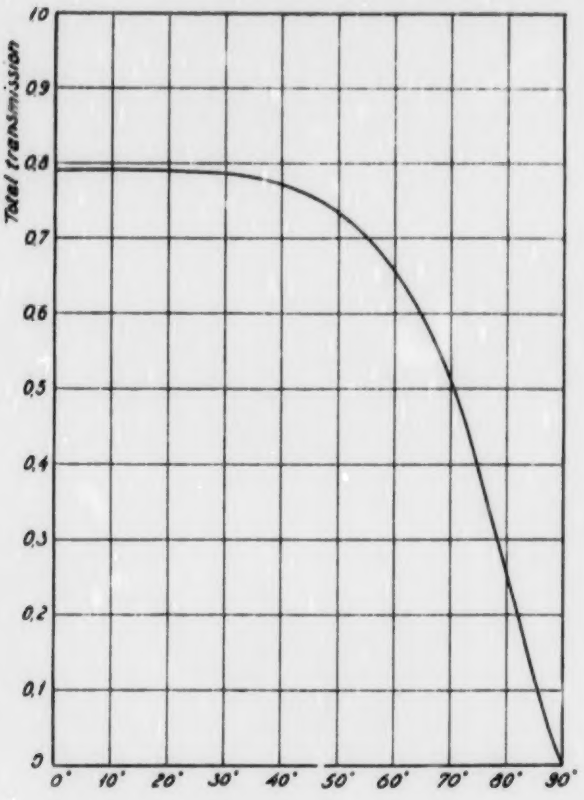


Figure 5. Total transmission for solar radiation by a double pane of common glass as a function of angle of incidence. E. Petersen: Solar Heat Gain Through Windows.

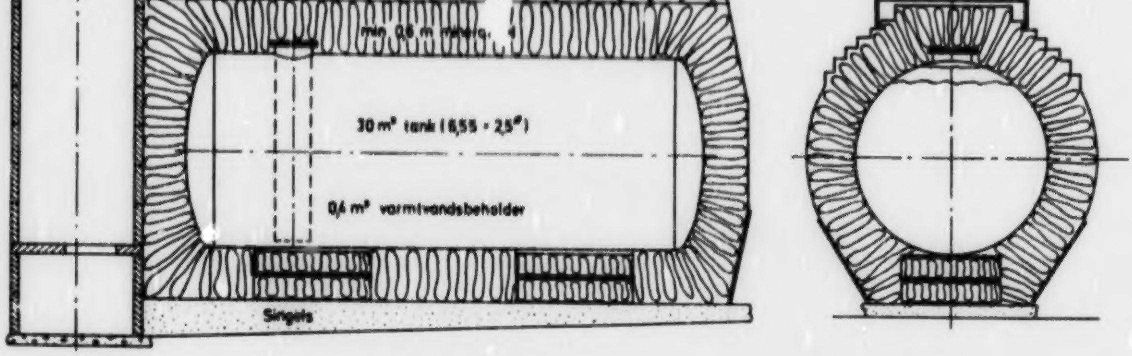

min 0,6 m mineraluld
30 m³ tank (6,55 · 2,5⌀)
0,4 m³ varmtvandsbeholder
Singels

Figure 6. Sketch of the accumulator buried just outside the house

FEDERAL REPUBLIC OF GERMANY:
SUMMARY OF 1976 SPECIAL FORMAT REPORTS

I. ADAPTION OF SOLAR HEAT PIPES AS ABSORBERS FOR A HOUSE HEATING SYSTEM IN MIDDLE EUROPE (DORNIER/RWE SOLAR HOUSE)

This project was started in 1974 by Dornier System and RWE, sponsored by the Federal Ministry of Science and Technology of the FRG. The Solar house is equipped with 70 m^2 Dornier heat-pipe collectors, an overall water storage capacity of 7.2 m^3 in the house basement, and a water-water heat pump, heating capacity 10 KW, to provide higher system efficiency during low winter insolation. The lowest evaporator temperatures is about 5°C, the highest condenser temperature is about 65°C with a coefficient of performance in the range of 2.8 to 3.8.

From April to September, the total heat demand of the house was supplied, in winter a minimum of only 10% was covered. Detailed data collecting and evaluation during 1977 and 1978 will result in an optimized solar heating system.

II. SOLAR TAP WATER HEATING PROJECT (CONTRACTOR: BROWN, BOVERI & CIE, AG)

PROJECT AIM

Experimental investigation and collection of data to prove the results of a study on the utilization of solar energy in Central Europe which had been carried out by BBC in 1973. Funding of DM 295,000 by the BMFT.*

PROGRAMME (15/3/74 – 31/12/75)

A. Basic Investigations on Solar Collectors

A computational analysis on the performance of solar collectors was made, including the influence of the construction and the outdoor conditions such as wind velocity, sky temperature, ambient temperature etc. A systematic analysis on a solar system for Central European climate was carried out.

B. Design, Construction and Testing of Solar Collectors

Collectors with single- and double-glass covers with an aperture area of 1.5 m^2 were constructed; 22 pieces were built. The experimental investigations tested the performance under stationary conditions and outdoor tests. A simple and reproducible method for the testing of solar collectors was proposed.

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*Bundesministerium für Forschung und Technologie

C. Development and Testing of Hot Water Supply Systems with Solar Energy

Seven experimental solar plants were built at different places in Germany and Austria. The results show that in the "non-heating season"** about 80% of the energy requirement for water heating of a one-family house can be contributed by solar energy. Recommendations for the specification of solar plants were made. The results of three systems were prepared for the CCMS Meeting in Copenhagen in the proposed format. One result is given in *Fig. 1*.

D. Investigations of Selective Layers

Investigations on selective layers for solar application extended on a computational analysis and the testing of chrome-oxide and tin-oxide in collectors. The development of silicon layers was stopped, as no economic production method could be found.

STATUS

The project was completed at the end of 1975. A report was submitted to the BMFT.

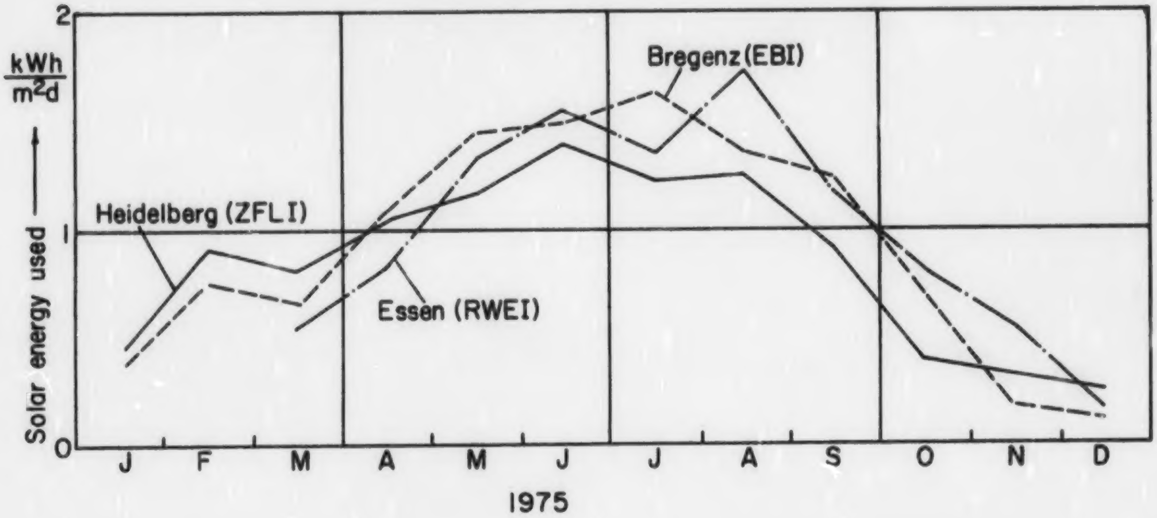

Figure 1. Mean monthly values of the daily solar energy used per square meter of aperture area of the solar collector for the three systems in 1975.

**In Central Europe, normally from May to September.

FRANCE: SUMMARY OF 1976 SPECIAL FORMAT REPORT *

J. F. Robert
National Center for Scientific Research (CNRS)

EXPERIMENTATION WITH SOLAR HEATED HOUSES AT ODEILLO

A report following the CCMS format, "Experimentation with Solar Heated Houses at Odeillo," was prepared by F. Trombe, J. F. Robert, M. Cabanat, and B. Sesolis of the CNRS Solar Energy Laboratory. The report concerns the thermal performance, over one year, of the solar heating device installed in the 1967 prototype houses built at Odeillo.

Solar collectors are placed on the east-west vertical plane (south vertical outer wall) owing to the many advantages derived from this arrangement. The energy is collected between a selective double covering (double glazing, for instance) and the absorbent surface of a heavy masonry wall which heats up. Part of the energy is transmitted to the air of the glass house which heats up in turn, rises by convective movement, and penetrates into the area to be heated by an opening at the top of the wall. Fresh air is drawn into the room naturally through a floor-level opening at the bottom of the wall. Natural convective thermocirculation is thus established, which begins as soon as the outer wall receives insolation and continues for two or three hours after insolation ceases depending on the amount of energy received during the day and external climatic conditions.

Another part of the energy is transmitted through the wall by conduction and results in a temperature rise in the wall's inner surface after a time lag that depends primarily on the type and width of the wall. The energy is then restored to the area to be heated by convection-conduction in the air and radiation towards the other surfaces. The average length of insolation during the "heating period" (October 1 – May 20) is about ten hours. The thickness and material of the wall must therefore be chosen in such a way as to provide for a 12-hour time lag approximately.

The results presented were determined on the basis of measurements made in the solar collectors (*Fig. 1*). These measurements are indicated on *Fig. 3* for four characteristic days. The results are determined on an hourly basis, totaled for a 24-hour period, and compared to the radiant solar energy during the day considered so as to determine the over-all output of the solar collector.

Figure 4 shows daily over-all output for a given number of fair days in relation to the average outside temperature. *Fig. 5* shows monthly over-all output in relation to the time of the year. It is interesting to note that output decreases as the summer solstice approaches because of the increase in the angle of incidence of direct radiation on the south vertical outer wall. This reduction in output is accompanied by a reduction of the solar energy radiating on the outer wall in question and corresponds to a reduction in heating needs. The selection of this collector plane seems therefore perfectly justified for a "passive" system using natural means of energy transmission.

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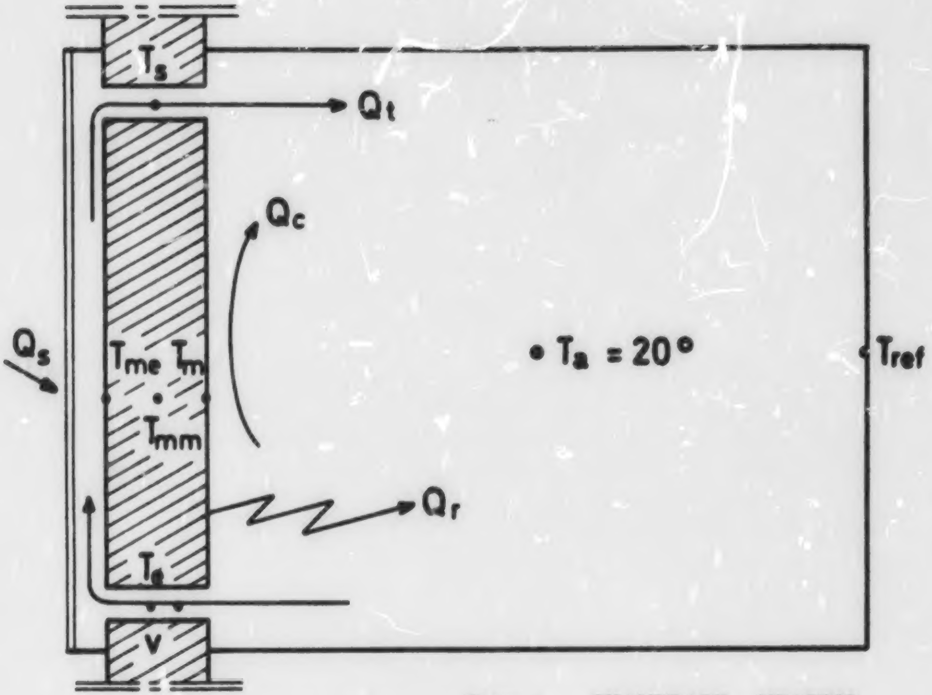
*Translation by U.S. State Dept.



Ts
Qt
Qc
Qs
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Ta = 20°
Tref
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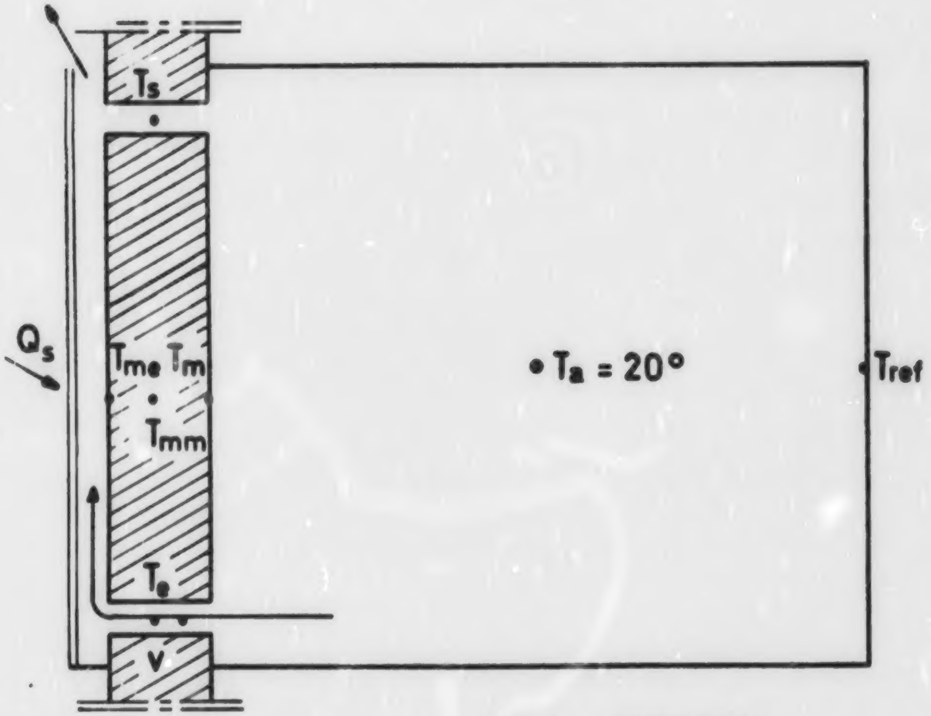
Figure 1. CHAUFFAGE – HEATING



Ts
Qs
Tme
Tm
Tmm
Ta = 20°
Tref
Te
V

Figure 2. VENTILATION

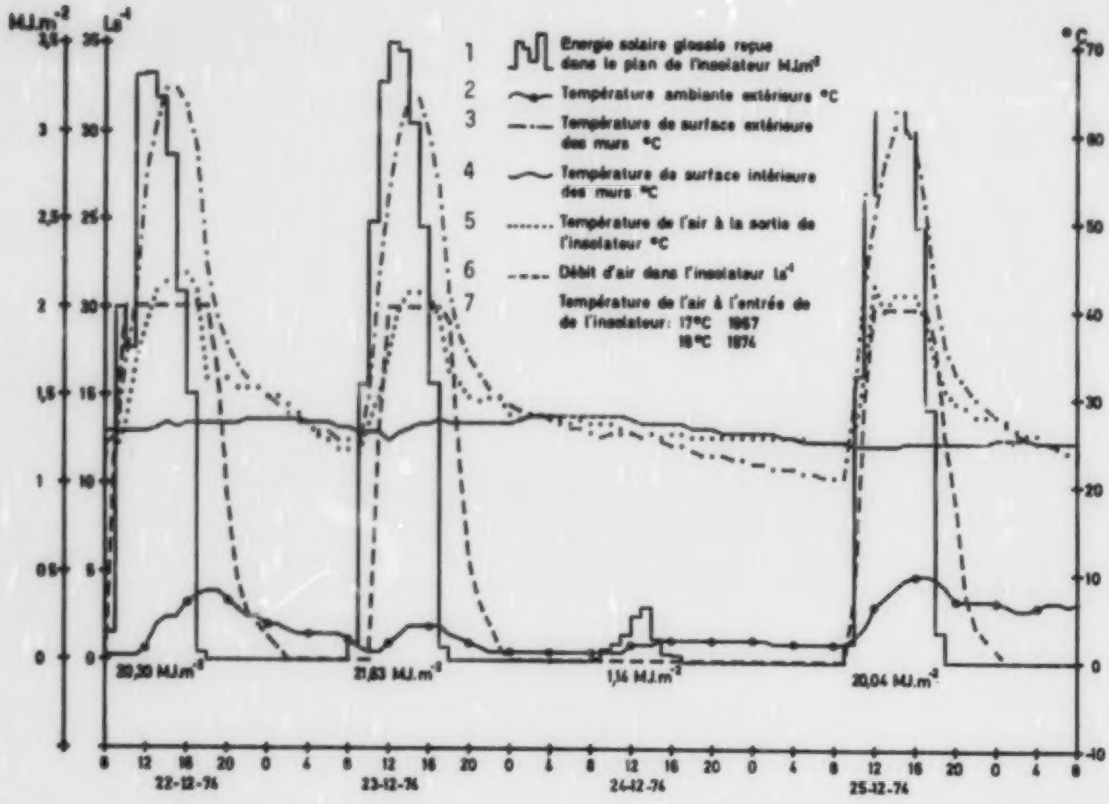


Figure 3. INSOLATEUR 1967 – SOLAR COLLECTOR

1. Overall solar energy radiating on the plane of the solar collector MJm^{-2}
2. Outside ambient temperature in ^{o}C
3. Temperature of outer surface of walls in ^{o}C
4. Temperature of inner surface of walls in ^{o}C
5. Temperature of air flowing out of solar collector in ^{o}C
6. Air flow in solar collectors Ls^{-1}
7. Temperature of air flowing into solar collector:
   17^{o}C 1967
   18^{o}C 1974

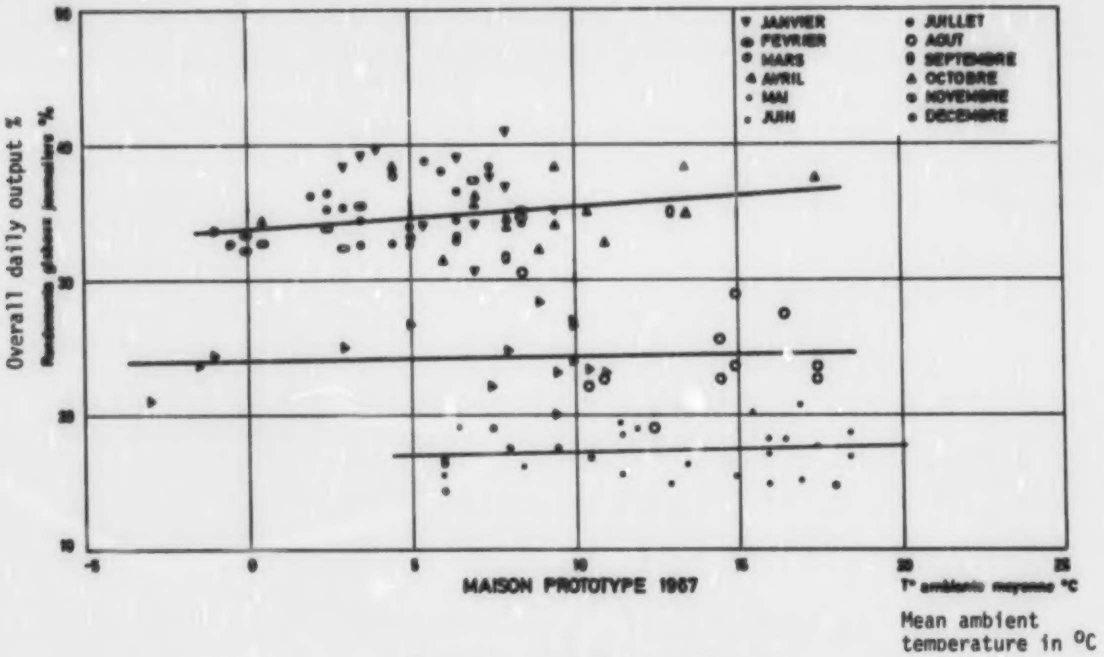


Figure 4. 1967 Prototype House

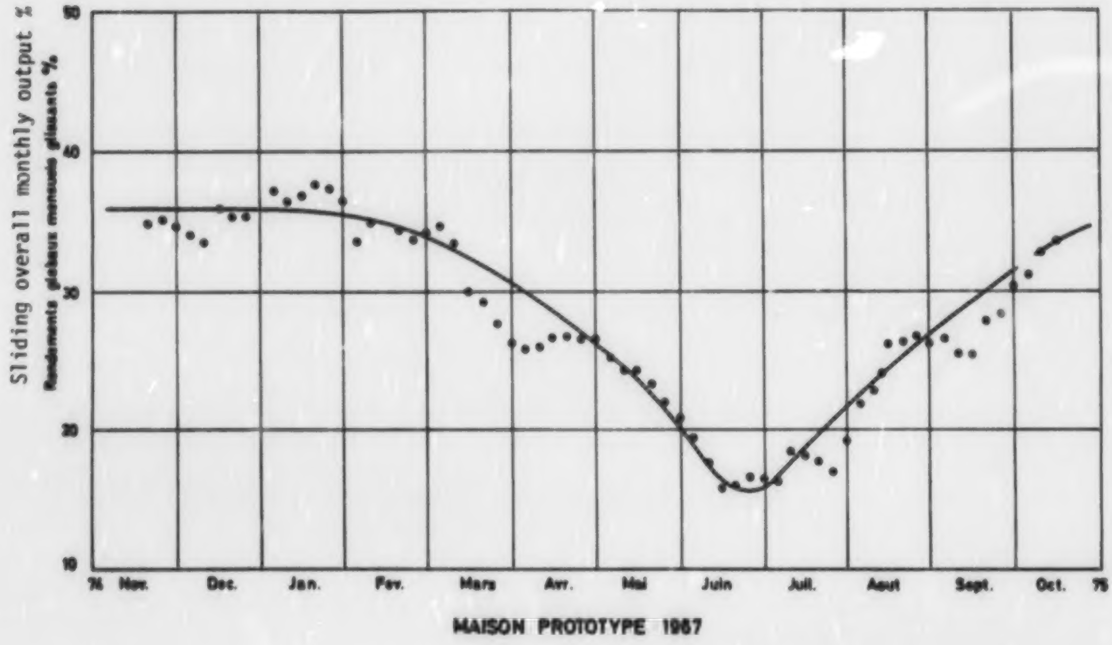


Figure 5. 1967 Prototype House

FRANCE: PRESENTATION DU RAPPORT SELON FORMAT CDSM

J. F. Robert
Centre National de la Recherche Scientifique

EXPERIMENTATION DES MAISONS A CHAUFFAGE SOLAIRE D'ODEILLO

Un rapport selon format CDSM, "Experimentation des maisons a chauffage solaire d'Odeillo," etait prepare par F. Trombe, J. F. Robert, M. Cabanat et B. Sesolis du Laboratoire de l'Energie Solaire du CNRS. Le repport concerne les biblans thermiques durant un an du dispositif de chauffage solaire equipant les Maisons Prototypes de 1967 construites a Odeillo.

Les insolateurs sont disposes dans le plan vertical Est-Ouest (facade verticale Sud) en raison des nombreux avantages que procure cette disposition.

L'energie est captee entre une double couverture selective (double vitrage, par exemple) et la surface absorbante d'un mur de maconnerie lourde qui s'echauffe. Une partie de l'energie est transmise a l'air de la serre qui s'echauffe a son tour, s'eleve par mouvement convectif et penetre dans le volume a chauffer par un orifice situe a la partie superieure du mur. De l'air frais est aspire naturellement dans la piece par un orifice se trouvant au niveau du plancher, a la partie inferieure du mur. Il s'etablit ainsi une thermocirculation convective naturelle qui s'amorce des le debut de l'insolation de la facade et se poursuit efficacement durant deux a troit heures apres l'arret des apports solaires suivant la quantite d'energie recue dans la journee et les conditions climatiques exterieures.

Une autre partie de l'energie est transmise par conduction a travers le materiau de stockage et se manifeste, avec un dephasage qui est fonction principalement de la nature et de l'epaisseur du mur, par une elevation de temperature de sa surface interieure. L'energie est alors restituee au volume a chauffer par convection-conduction dans l'air et rayonnement vers les autres parois. La duree moyenne d'insolation durant la "periode de chauffage" (ler Octobre – 20 Mai) est de l'ordre de 10 heures. L'epaisseur et le materiau du mur doivent donc etre choisis de facon a menager un dephasage de l'ordre de 12 heures.

Les bilans presentes ont ete etablis sur la base des mesures effectuees dans les insolateurs (*Fig. 1*). Ces mesures sont regroupees *Fig. 3* pour quatre journees caracteristiques. Les bilans sont effectues heure par heure, sommes sur 24 heures, et compares a l'energie solaire incidente durant la journee consideree en vue de la determination d'un rendement global de l'insolateur.

La *Fig. 4* represente des rendements globaux journaliers pour un certain nombre de journees claires. Ils ont ete portes en fonction de la temperature exterieure moyenne.

La *Fig. 5* represente les rendements globaux mensuels en fonction de la periode de l'annee. Il est interessant de remarquer que les rendements diminuent au fur et a mesure que l'on se rapproche du solstice d'ete du fait de L'augmentation de l'angle d'incidence du rayonnement direct sur la facade verticale Sud. Cette diminution du rendement s'accompagne d'une diminution de l'energie solaire incidente sur le plan considere et correspond a la reduction des besoins en chauffage. Le choix de ce plan recepteur semble donc parfaitement justifie pour un systeme "passif" utilisant des moyens naturels de transmission de l'energie.

GREECE: SUMMARY OF 1976 SPECIAL FORMAT REPORT

Greek Atomic Energy Commission
Nuclear Research Center "Demokritos"

REFLECTING HORIZONTAL SOLAR COLLECTOR

The following is an interim format report. A full special format report will be prepared upon completion of testing of the system.

GENERAL DESCRIPTION OF PROJECT

The Greek Atomic Energy Commission approved in May 1975 a solar research program, which includes heating and cooling of buildings. The first phase provided for the conversion of the conventional heating system of 3 rooms (90m^2) in an existing building. Because of delayed delivery of the materials for the construction of the collectors, this project was abandoned, as it could not be ready for operation in the winter period 1976.

The original project has been extended to provide for the heating by solar energy of 12 rooms in the recently constructed administration building of the Nuclear Research Center "Demokritos". These rooms are heated and cooled by an independent loop and can be automatically switched any time to the solar heated storage tank or to the conventional heating system.

The rooms have an area of about 450m^2 and a large thermal load because of many single pane windows and insufficiently insulated walls.

It is expected that the system will be tested in the winter months of 1977. In the mean time a type of reflecting horizontal collector was developed, which is being evaluated. This collector will be used in the heating project under construction.

DESCRIPTION OF THE ENVIRONMENT

The Nuclear Research Center "Demokritos" is located approximately 10 kilometers NE from the centre of Athens, Greece. The climate of the general area can be characterized as mild with mean temperatures ranging between 9°C and 27°C. The climatological data shown in *Table 1* refer to the climate in the general Athens area. The mean annual rain is about 500mm per year. The yearly cloudiness is 4.2 tenths and the total hours of sunshine for an average year are about 2,7000 hours.

Table 1

Meterological data taken at the National Observatory of Athens
Location: 37° 58.3' Latitude, 1 h 34.9 min Longitude and 107 m Altitude.

MONTH	SOLAR INSOLATION* kcal/m^2-day	MEAN AMBIENT TEMPERATURE °C	WIND** m/sec	AVERAGE DAILY HOURS OF SUNSHINE	SUNSHINE HOURS PER MONTH	CLOUDINESS TENTHS MONTHLY
January	1640	9.0	3.9	4.3	124	6.2
February	2400	9.5	4.1	5.5	138.2	6.0
March	3300	11.5	3.7	5.8	185.4	5.4
April	4560	15.2	3.2	8.0	233.3	4.7
May	5330	19.7	3.0	10.1	263.7	4.4
June	5880	24.1	3.1	11.5	307.3	2.9
July	5970	27.2	3.9	12.6	360.7	1.3
August	5360	27.0	3.8	11.9	341.5	1.3
September	4170	23.4	3.4	9.2	275.2	2.3
October	2910	19.0	3.1	7.0	209.6	4.3
November	1970	14.6	3.5	5.6	143.2	5.8
December	1480	11.0	3.6	4.4	116.9	6.2

DEVELOPMENT OF A REFLECTING HORIZONTAL COLLECTOR

Tilted flat plate collectors leave a space behind each row of collectors, which cannot be used because of shadow. Attempts have been made to use this space with reflecting surfaces in order to increase the incident solar radiation on the following collector row.

On the other hand, tilted collectors require a supporting structure on flat areas or collector arrangements on roofs which affect the architecture of the buildings, e.g. the characteristic architecture of solar houses.

On buildings with flat roofs the ideal solution, from the point of view architectural configuration, would be a horizontal flat plate collector, instead of a tilted one, because it would not be visible from the surroundings and it can be installed easily at any existing building.

The collector is composed of a number of parallel small pipes with fins. Whereas the collector is placed horizontally, with a slight inclination for drainage purposes, a tilt is given to the fins similar to that of a conventional collector at the same latitude. The upper part of *Fig. 1* shows various configurations of the piped fins. A reflecting surface is adapted in the space between two consecutive finned pipes, so that the collector consists of alternate stripes of tilted absorbing fins and reflecting surfaces, as shown in the lower part of *Fig. 1*. The prototype collectors tested both had a single glass pane.

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*Average daily solar radiation on horizontal surface
**Average monthly wind speed

The total heat absorbing surface of the prototype collector has an area of 1.75m^2 and the total horizontal area occupied by the collector as a whole is about 3.30m^2. The cost increase is about 20% and is more than compensated for by reduction in cost of supporting structure.

According to the sun's position a reflection takes place, which increases the amount of incident solar radiation on the absorbing black surface. Significantly higher temperatures are obtained in the circulating fluid.

Figure 2 shows the efficiency of the prototype collectors versus a standard collector, made of the same materials and having the same tilt as the fins, but without reflecting surfaces. Inlet temperatures were varied from 38 to 80°C. Mass flow 0.095 and 0.143kg/m^2 sec. It can be seen that the efficiency of the prototype collectors is very close to the double of the corresponding conventional collector.

Figures 3 and *4* show the temperature rise Δt in °C versus solar radiation or fluid inlet temperature and *Fig. 5* the variation of the efficiency versus inlet temperature, for both the conventional tilted collector and the prototype horizontal collectors.

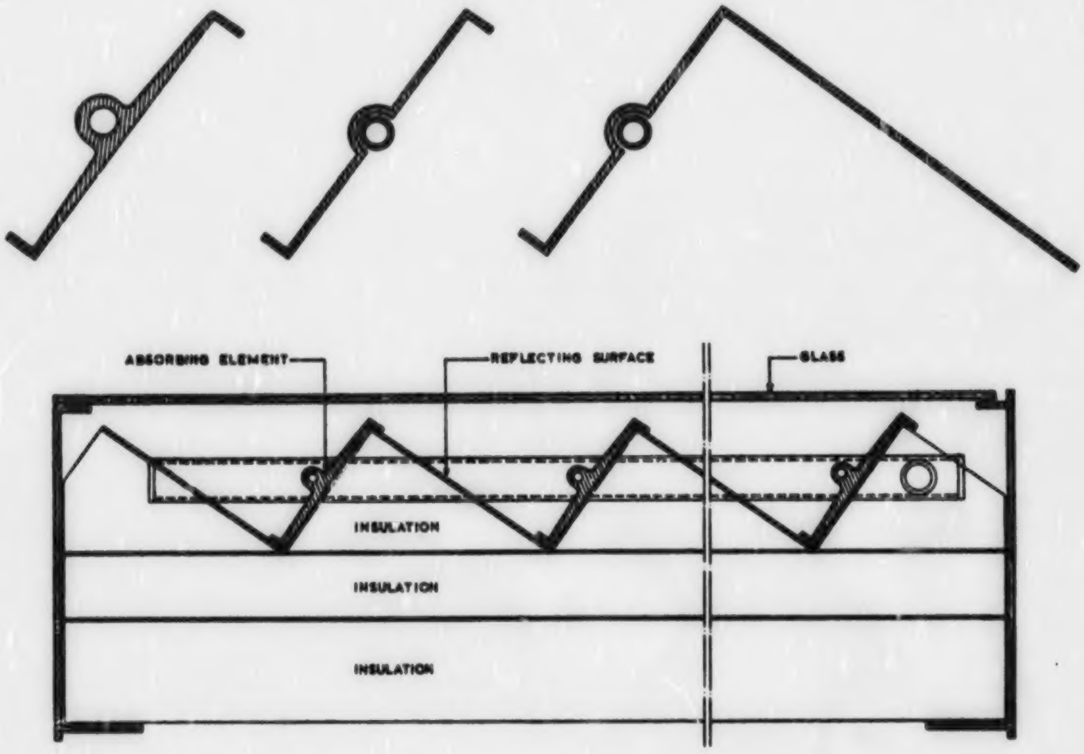


Figure 1

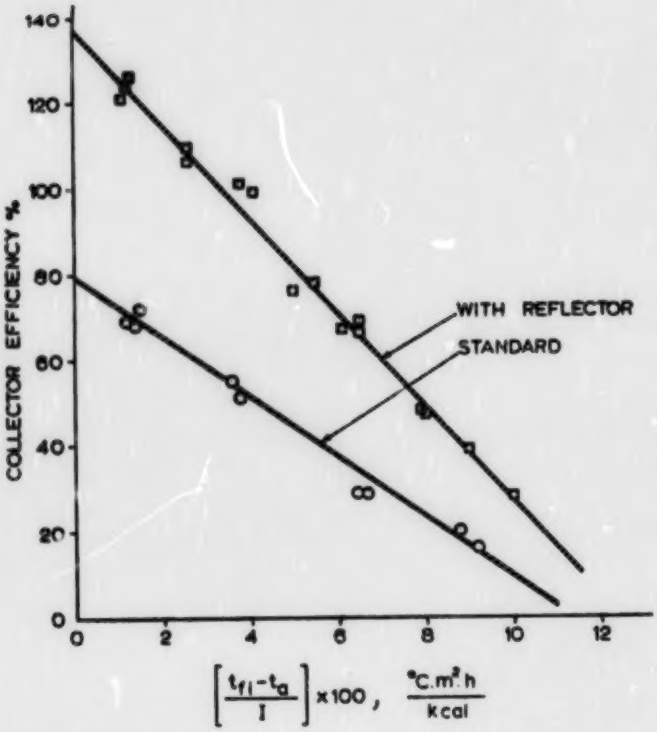


Figure 2

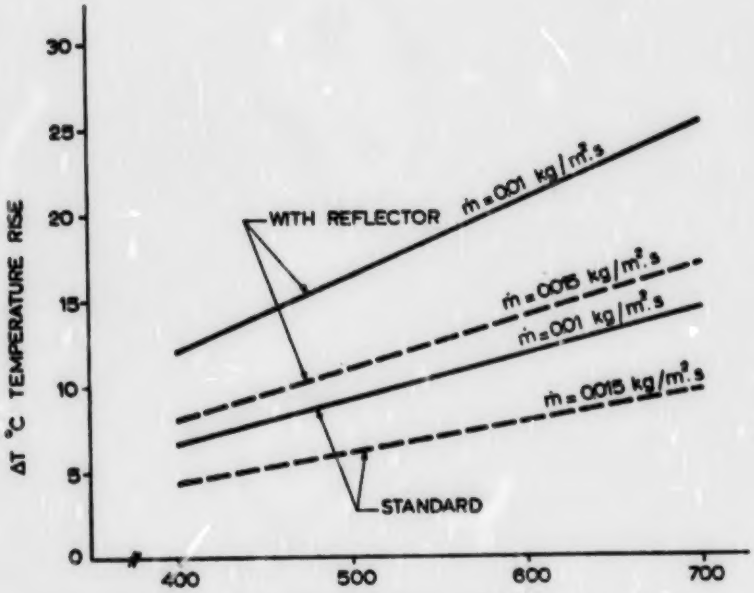


Figure 3

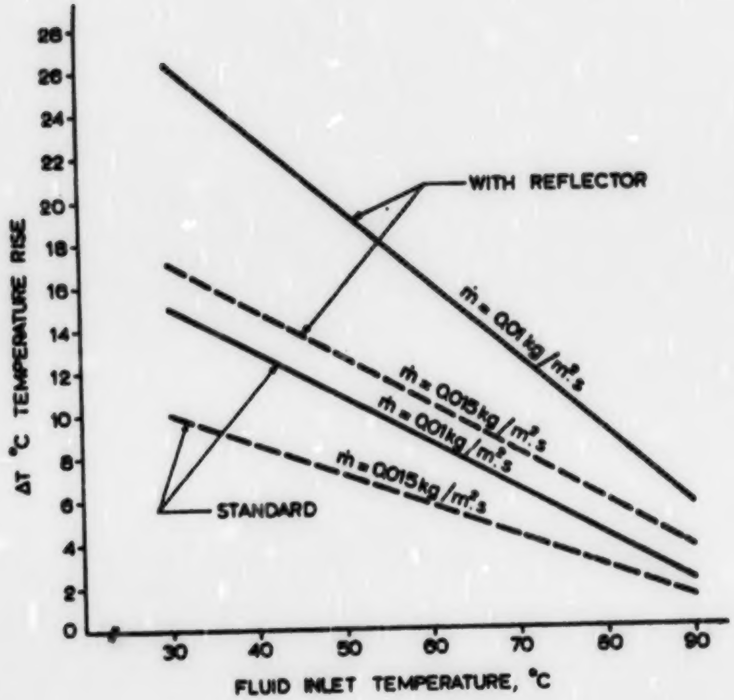


Figure 4

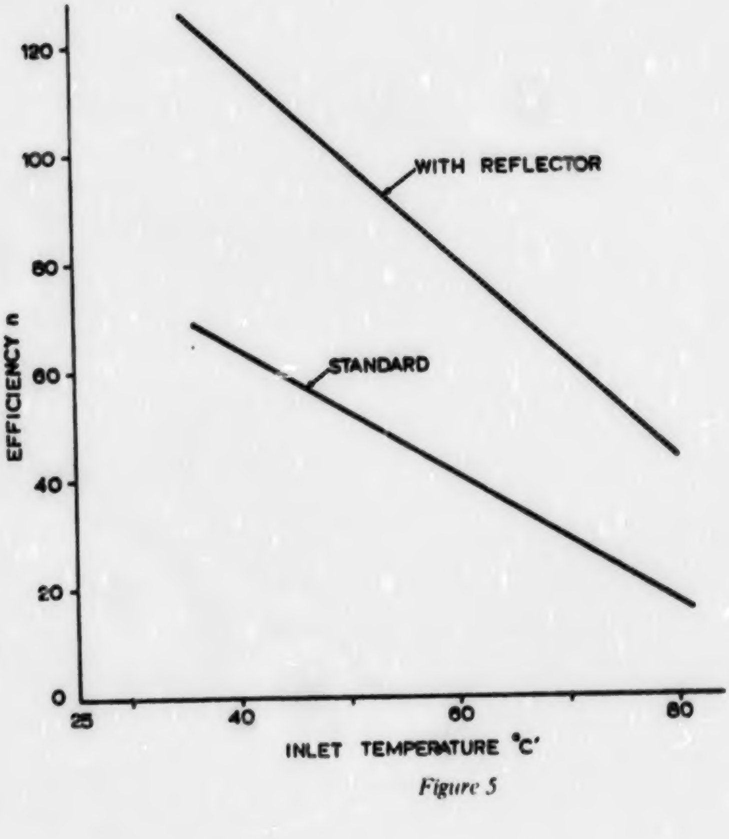


Figure 5

SWEDEN: SUMMARY OF 1976 SPECIAL FORMAT REPORTS

Per Isakson and Egil Öfverholm
Royal Institute of Technology

EUROC AB-SOLAR ENERGY BUILDING IN LIMHAMN (THE "TERMOROC" HOUSE)

I. GENERAL DESCRIPTION OF SYSTEM, PROJECT AND ENVIRONMENT

I.A Objective of Project

Erection of a full-scale low-energy experimental house (*Fig. 1*) with an energy requirement reduced at least 50 percent as compared with a corresponding normal building.

Technical evaluation of the product prototypes includes an improved living and working environment as well as energy recovery and conservation in order to acquire technical know-how.

Architectually and aesthetically acceptable performance of integrated solar collector ramp in the framework of the building.

Close following up of the cost for the devices installed with regard to the costs of development, planning, materials and installation as well as an economical evaluation of the energy saving achieved.

Further development of the most promising demonstrational prototypes for consumer products from a technical - economical point of view.

In order to achieve the objective of the first item, the following principles are applied:

- The coefficient of thermal transmittance for walls and roofs is less than $0.3 W/m^2 {}^{\circ}C$.
- Careful sealing between units in the building.
- Concentration of windows towards the south walls.
- Improved insulation of windows.
- Reduction and regulation of natural ventilation.
- Heat recovery from waste water.
- Partial solar heating.
- Supplemental heating by off peak electricity stored in hot water.

- Heat distribution by means of low-temperature-water in coils in the floor slab.
- Control of space heating system.

Time schedule: The building was completed in November 1975 and measurements have been carried out since that date.

I.B Description of the Environment

Location

The building's location is at 55° 35′ N latitude, 12° 57′ E longitude, and the elevation is 3m above mean sea level.

There are no buildings or trees which overshadow the solar collectors. Contact person: Bengt Rosengren, Euroc AB, Malmö.

Climate

The type of climate according to the Trewartha classification is: Dbf (Humid continental and cool summer). The climate in Limhamn is similar to that in Lyngby, Denmark, where the "Zero Energy House" is situated. See climate report for that project.

I.C Description of the Entire System

- Solar heating system

42 solar collectors (*Figs. 2* and *3*) each having a surface area of one m^2 are placed in the roof of the building at an inclination of 70 degrees.

The solar collectors are double glazed; the outer glass being U-shaped and self-supporting. The solar collectors are connected in series of vertical groups of four. In front of the solar collector ramp there is a roof with a reflecting surface.

When the water from the solar collector becomes cooler than that in the accumulator tank the solar collector is automatically drained. The water then flows back into the tank and nitrogen gas which has been stored above the water surface of the tank rises and fills the solar collector which is then protected against internal corrosion and freezing.

When the solar collector is sufficiently heated by radiation the solar heating circuit (*Fig. 2*) starts automatically. The solar collector is then filled with water and the nitrogen gas is displaced back into the tank where it serves as an expansion volume.

In the summertime the solar collector is also drained automatically if both the temperature of the tank and that of the solar collector exceed +95°C.

An additional $10 m^2$ solar collector will be installed during 1976.

- Heating system

The heat from the storage tanks is distributed via pipes in the concrete floor slabs.(*Fig. 3*). The minimum temperature of the water is 28°C at an outdoor temperature of -10°C. During rapid weather changes the supply air may be heated by direct electric means.

- Heat storage

Two steel tanks with a total of 3100 l water have a heat storing capacity of 237 kWh (+30°C - 95°C). The heat capacity in the floor slabs is 18 kWh/K.

The calculated heating requirement of the building is 284 w/°C which means that the stored heat will last for 42 hours at an indoor temperature of +20°C and at an outdoor temperature of ±0°C. The system with two tanks allows a flexible utilization of solar energy and cheap night-electricity.

- Hot-water

Cold water is pre-heated by the delayed outlet of hot water. The additional heating takes place in a 120 litre storage tank in each of the accumulator tanks. (See "Dom. Hot", *Figs. 2* and *3*). At the taps a highest hot water temperature of +45°C is desired in order to utilize solar heat as far as possible.

- Measuring system

Radiation has been measured by means of two solarimeters from R+B Messatechnik, Göttingen. They have the same orientation as the solar collector and one of them is shaped for direct solar radiation by means of a semi-circular steel strip. The high value in January 1976 was because this month was extremely sunny, because the reflector is effective near the low solstice in January and because the solarimeters most probably were defective.

The collected solar heat is measured by means of a heating volume indicator ((SVM) and by means of a 12-channel recorder (Philips Transokomp 288)) which records the supply and exhaust pipe temperatures. The water flow is read on a separate water meter.

In order to evaluate e.g. the solar collectors in greater detail a 6-channel datalogger (Doric Digitrend 210) is used. The measured data are also recorded on a paper tape for further processing in a computer. This equipment has been in operation since March 1976.

II. SYSTEM THERMAL PERFORMANCE

Figures 4, 5 and *6* are based on measuring data, extrapolated measuring data and calculations.

All values taken before 1st February 1976 are uncertain since the solar heating system was not sufficiently adapted before that. Comprehensive works were also in progress in the house during certain periods.

One person has been working in the building only during day-time. That explains why the items body heat, domestic electricity and hot water are very small.

The energy requirement for heating has been measured by means of a heating volume indicator in the floor heat circuit.

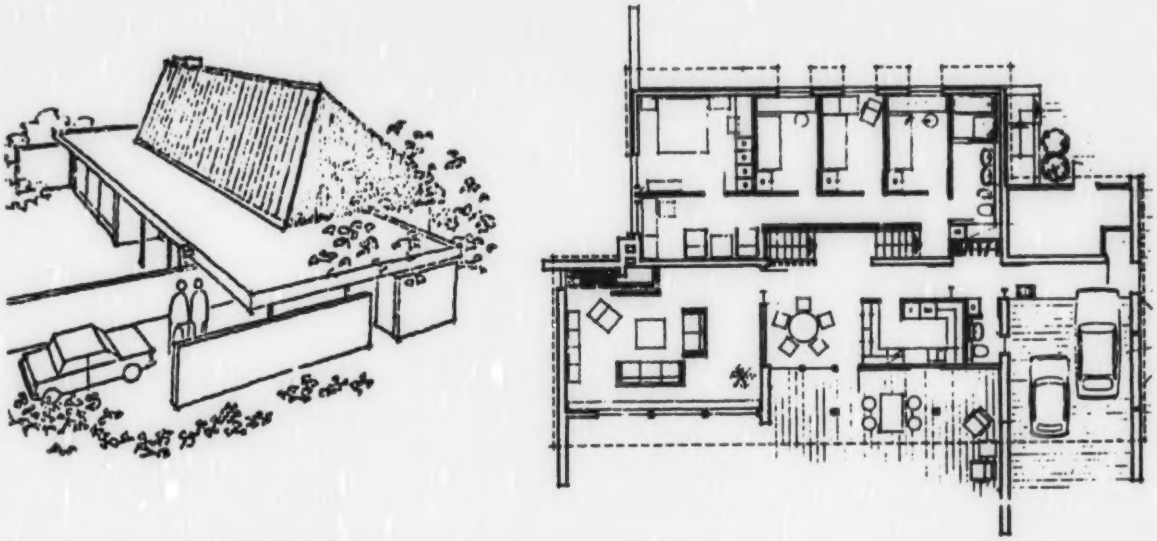


Figure 1. THE "TERMOROC HOUSE," A ONE-FAMILY HOUSE, 150 m^2

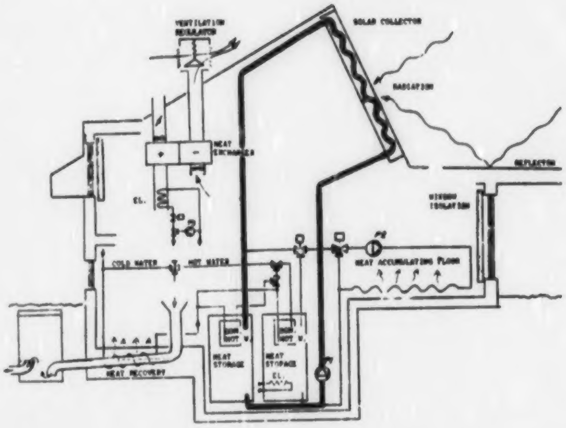
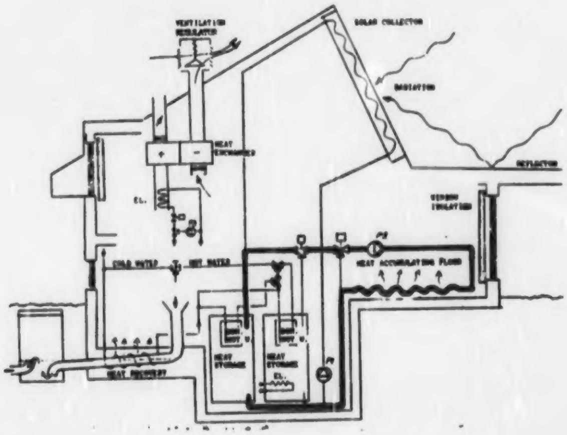

VENTILATION REGULATOR
SOLAR COLLECTOR
RADIATION
HEAT EXCHANGER
REFLECTOR
EL.
WINDOW ISOLATION
P2
COLD WATER
HOT WATER
HEAT ACCUMULATING FLOOR
DOM. HOT W.
DOM. HOT W.
HEAT STORAGE
HEAT STORAGE
EL.
P1
HEAT RECOVERY

Figure 2. SOLAR COLLECTOR – STORAGE WATER FLOW 0.25 1/min, m^2 COLLECTOR

Figure 3. STORAGE – HEATING WATER FLOW 21 1/min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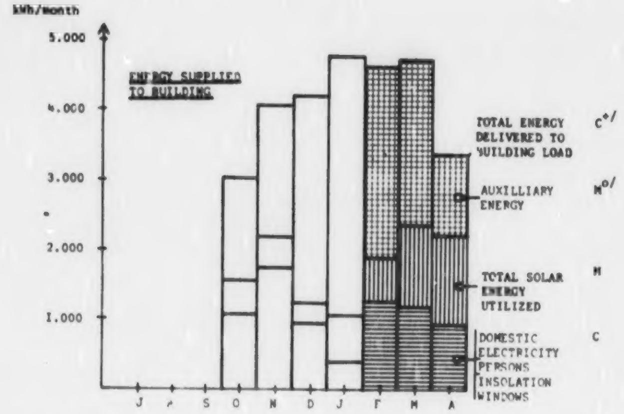
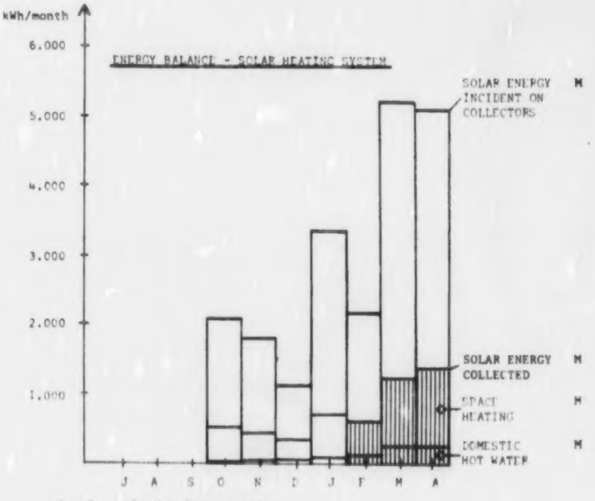


Figure 4. ENERGY SUPPLIED TO BUILDING



*/ C - Calculated Energy Flows
o/ M - Measured Energy Flows

Figure 5. ENERGY BALANCE – SOLAR HEATING SYSTEM

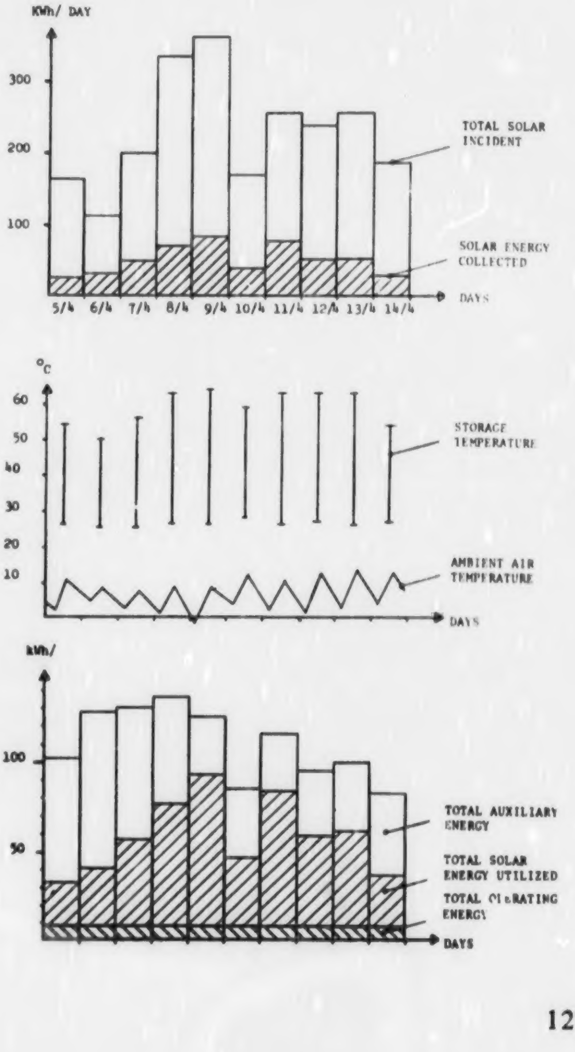


Figure 6. THE THERMAL PERFORMANCE OF THE SOLAR ENERGY SYSTEM DURING TEN DAYS IN APRIL 1976.

(The reason for the apparent anomaly in the total building load is that the amount of energy stored in the heavy slab varied during the period.)

AB OSTGOTABYGGEN –
SOLAR ENERGY BUILDING IN LINKOPING

I. GENERAL DESCRIPTION OF SYSTEM, PROJECT AND ENVIRONMENT

I.A Objective of Project

The aim of the project has been to build into a conventional one-family house a solar heating system contributing 40-60 per cent of the energy requirement for space and water heating.

This pilot study with its small heating plant could offer experience for the construction of a larger plant for several houses.

To develop from a technical and economical point of view new, simpler types of solar collectors and more efficient thermal storages.

The house and the solar energy system should as far as possible be constructed from units available on the market.

In connection with functional tests, the system should be studied for simplifications allowing the construction of less expensive systems.

Time schedule:

1973-10-15	Preparatory planning and literature studies
1974-06-15	Preparatory designs and studies
1974-08-01	Design of heating system and building
1974-08-15	Development of a system for protection against corrosion
1974-12-01	Start of construction
1975-04-01	Solar energy system completed
1975-06-17	Moving-in date
1975-07-01	Start of measurements

Measurements have been in progress during the heating season 1975-76, during which period a family lived in the house.

I.B Description of the Environment

Location

The building's location is at 58° 22.5′ N latitude, 15° 41.9′ E longitude, and the elevation is 67 m above mean seal level. Lövsbergsvägen 36, Linköping.

Contact person: Bertil Dättermark, AB Östgötabyggen, Linköping.

The distance to the Baltic is about 80 km, East. The distance to Lake Roxen is about 9 km, West. The distance to the Stångå River is about 1 km. The building is located so that one of its long sides faces towards SSW. The terrain is flat and open and the house is sited completely free towards the South up to a distance of 130 m where a forest area starts with about 22 m high trees (*Fig. 1*). This means that the trees shade the sun when the solar elevation angle is less than 8°. Screening from the forest area is noticeable during winter-time. According to Hoglund & Stephenson's tables the sun's angle of elevation is 8.6° at noon on 21st December on 50°N.

The air in and around Linköping is clean but because of the aeroplanes the amount of cirrus clouds has increased significantly.

Climate

Type of climate according to Trewartha: Dbf. Annual rain and snowfall: 545mm. Amount of days with snow cover: mean value 97. At least 50% of ground covered with snow: 27/11 - 7/4. White frost - 130 days/year. The humidity varies between 65 and 90% with a peak during winter. The direction of the wind is mostly W or SW. Solar radiation data and dry-bulb temperature data are given in *Figs. 2, 3,* and *4.*

I.B Description of the Entire System

Description of building

The building (*Fig. 5*) to be used as a one-family-house. It is cellar-less, built on a concrete base and consists of a wood framework and wood intermediate floor structure. In order to reduce the heat losses, the facade is closed towards the north and provided with fixed windows with three panes (7. 5 m^2) and additionally triple-glazed windows that can be opened.

U-Values:
- Walls 0.26 W/m^2 °C
- roof 0.33; 0.19 W/m^2 °C
- floor 0.25; 0.28 W/m^2 °C
- windows 2.05 W/m^2 °C
- ventilation 0.067 m^3/sec.

Description of installed systems

- Solar heating system

The heat collected by the solar collectors (50 x 1 m^2) is stored in an accumulator (8 m^3) located in the garage. (*Fig. 6*).

The circulation pump for the solar collectors starts when the temperature at the solar collectors is higher than the temperature at the bottom of the accumulator and stops automatically when the temperature is lower than that at the bottom.

When the pump stops the system is drained of water and is filled with nitrogen gas from two nitrogen accumulators on the outer roof.

The water from the solar collectors is collected in an expansion vessel placed at a low level.

The water flow through the solar collectors may be varied from 0.33 to 1.0 litre per second.

There is an additional water tank (3.2 m^3) for the storing of cheap night electricity.

- Heating System

The solar heated water is used for heating when the temperature of the water is sufficiently high (*Fig.* 7). The battery in the hot air plant is dimensioned for half of the heating requirement at a supply temperature of 45°C and an exhaust temperature of 25°C. This means that the solar heated water may be used down to an outdoor temperature of 0°C if the accumulator has a highest temperature of 45°C. The hot air plant circulates 0.22 m^3 air per second. Required addition of outdoor air may be performed by means of a manually controlled valve.

- Hot water system

The hot water is heated by means of a heat exchanger in the solar heating or electrical heating tank up to a temperature of 42°C.

Description of measurement system

Measurements have been recorded with the family living in the house.

Temperature sensors are placed on the underneath side and on the top side of the solar collector at the ridgepole and at the eave and at the supply and exhaust pipe lines from the solar collectors on five different heights in the tank.

A heating volume indicator (Kamstrup 85-16-121) measures the energy quantity above the solar collectors.

Measurement of solar radiation has at times been made by means of a solarimeter (Kipp No. 621 881) at the same angle as the solar collectors, i.e. at 45°.

Temperatures are recorded on a 12-channel Honeywell recorder once every hour. The reduction of the measured data has been very tedious.

II. SYSTEM THERMAL PERFORMANCE

The solar heating system functioned very well from a technical viewpoint during the test year. However, the solar energy collected was less than expected. (*Fig. 8*)

The solar radiation during autum 1975 was less than normal and the temperature of the solar storage tank decreased more rapidly than expected.

As from November, the solar energy was mainly used for the preheating of the hot water.

During January the solar collectors were partly shaded by trees in a forest area to the south.

The direct radiation through the window of the building was also very small.

Snow and above all white frost on the solar collectors also contributed to a reduction of the collected energy. However, the snow fell off relatively rapidly from the solar collectors which were also cleaned by the snow.

IV.A Solar collectors

The southern outer roof surface consists of a collector of 50 m^2 built in situ. (*Fig. 9*) The radiators are constructed in Denmark and are of the same performance as those in the Danish "Zero energy building". They are 200 x 50 cm and contain water as a heat transferring medium. The radiators are made of steel and have a selective black coating consisting of black chrome on top of zinc. The underneath surface is insulated with 15 cm mineral wool and the top surface is covered with 25 mm insulating glass (5 mm glass + 15 mm interspace + 5 mm glass). In order to prevent cracking the glasses are manufactured at a greater negative pressure than normal.

The collector and storage thermal performance are summarized in *Figs. 10* and *11*.

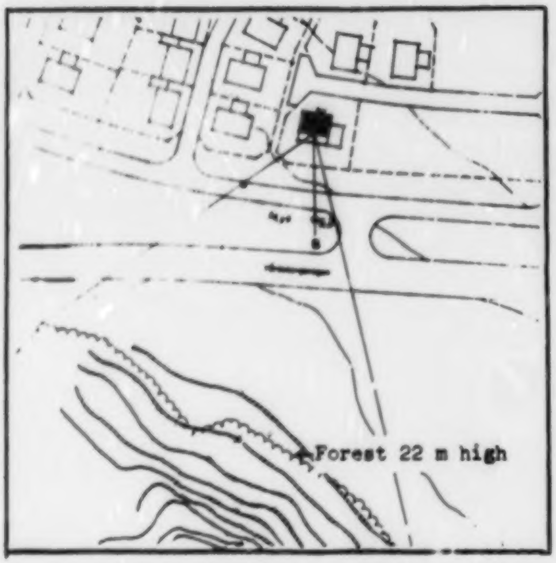
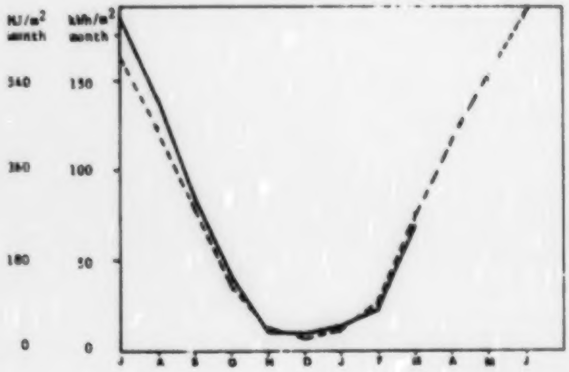
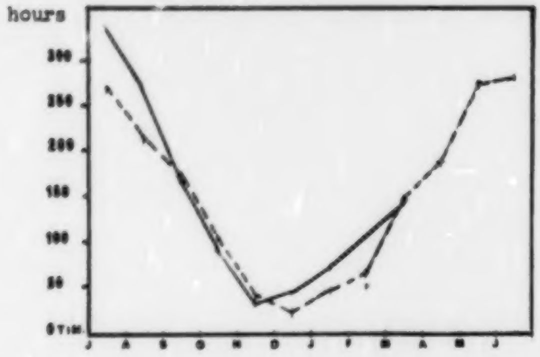


Figure 1. SOLAR HOUSE LOCATION



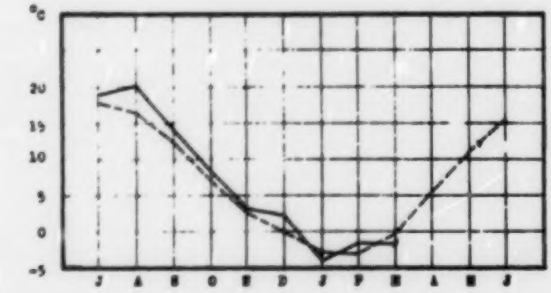
----- 1958-1969	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
—— 1975-1976	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Figure 3. GLOBAL RADIATION ON A HORIZONTAL SURFACE IN STOCKHOLM, 200 KM NE. THE INSTRUMENTATION CONSISTS OF A SOLARIGRAF, TYPE MOLL-GORCZYNSKI



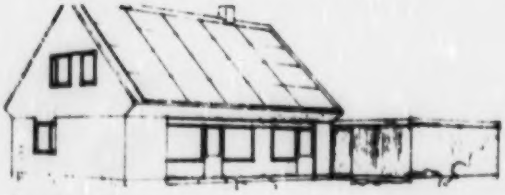
NORMAL - - -	266	214	172	104	42	24	46	66	149	189	274	280
1975-76 ——	330	260	166	91	33	61	72	81	145			

Figure 2. SUNSHINE HOURS IN NORRKOPING

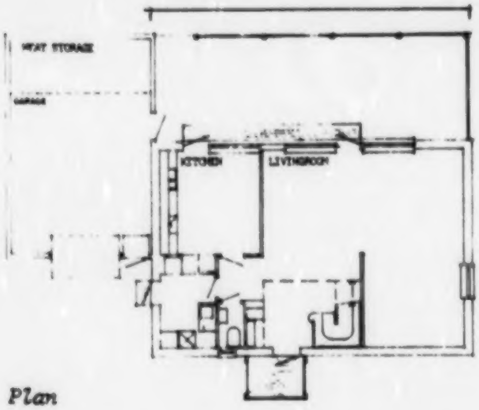


	J	A	S	O	N	D	J	F	M	A	M	J
Normal - - -	17,7	16,4	12,2	7,1	2,7	0,0	-2,9	-3,0	-0,1	5,3	11,0	15,4
1975-1976 ——	18,8	20,1	14,0	8,1	3,1	2,2	-4,1	-1,6	-1,8			

Figure 4. AMBIENT DRY BULB TEMPERATURE



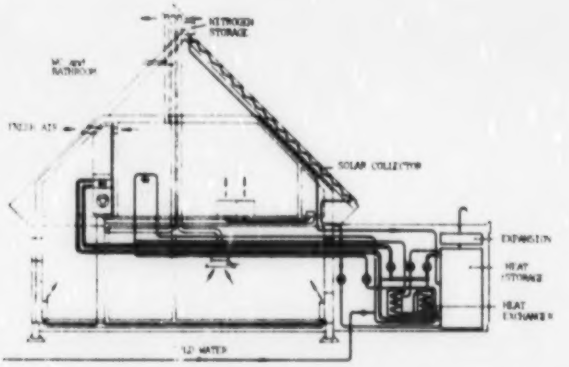
Perspective


HEAT STORAGE
GARAGE
KITCHEN
LIVINGROOM

Plan

Figure 5. ÖSTGÖTABYGGEN SOLAR HOUSE

Figure 6. SOLAR COLLECTOR – STORAGE


NITROGEN STORAGE
WC and BATHROOM
FRESH AIR
SOLAR COLLECTOR
EXPANSION
HEAT STORAGE
HEAT EXCHANGER
COLD WATER

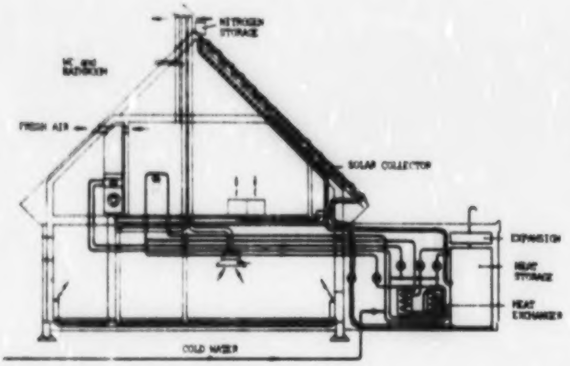
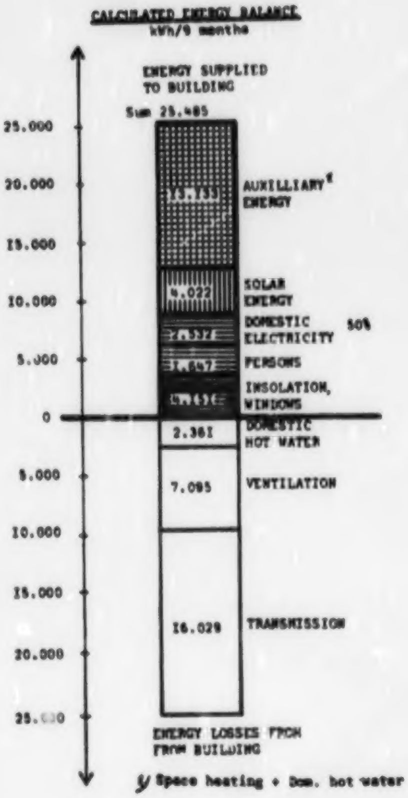
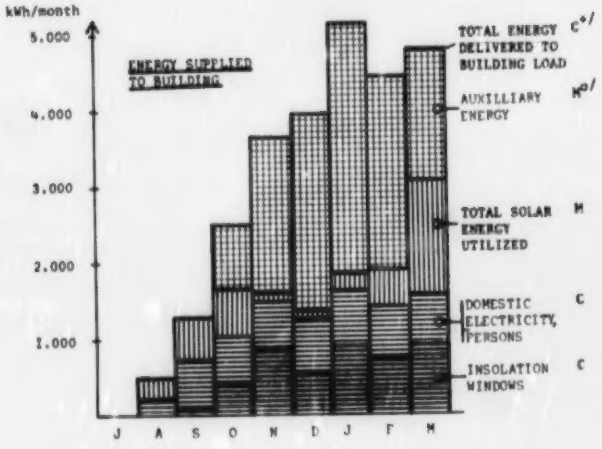

NITROGEN STORAGE
WC and BATHROOM
FRESH AIR
SOLAR COLLECTOR
EXPANSION
HEAT STORAGE
HEAT EXCHANGER
COLD WATER

Figure 7. STORAGE – HEATING





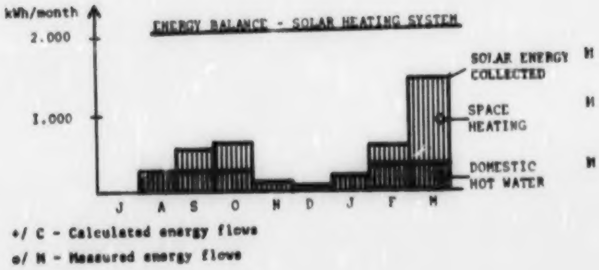


Figure 8. SYSTEM THERMAL PERFORMANCE (The heat losses from the building have been estimated.)

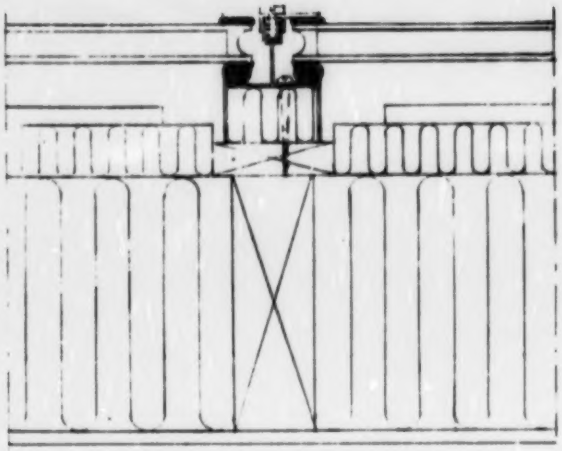


Figure 9. SOLAR COLLECTOR

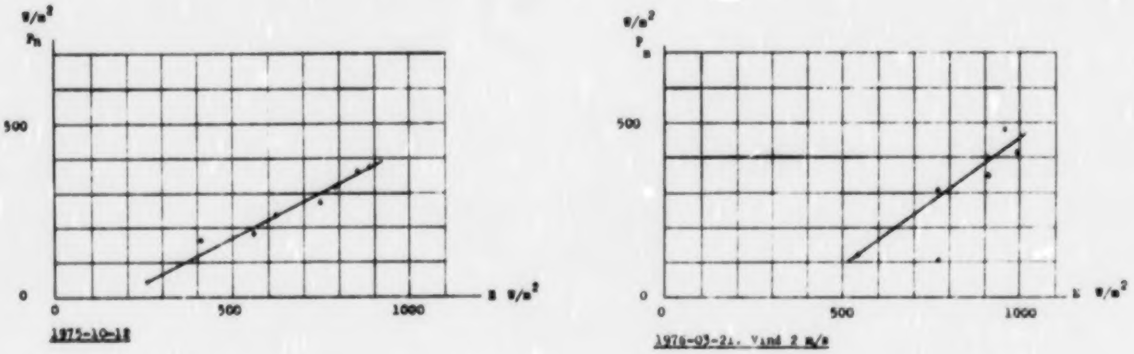


Figure 10. THERMAL PERFORMANCE OF THE SOLAR COLLECTOR (P_n = collected effect : E - insolation)

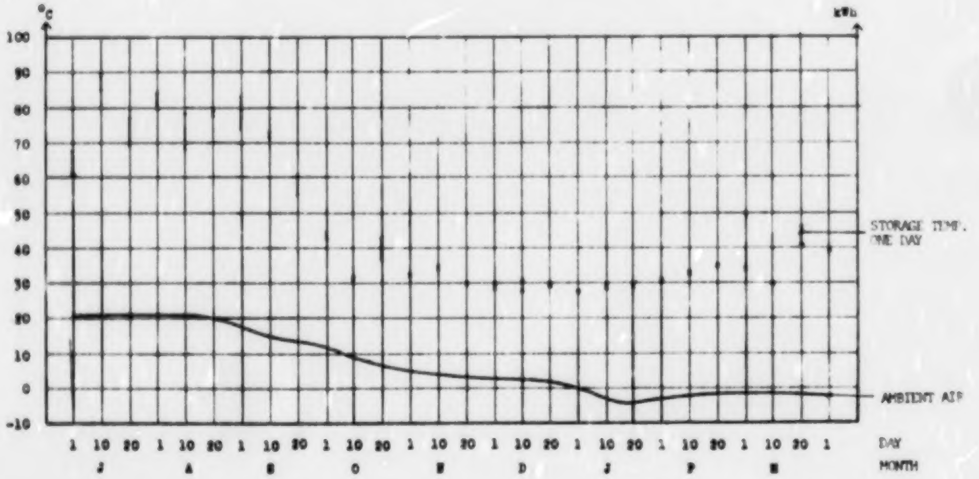


Figure 11. HEAT ACCUMULATION IN STORAGE

SVERIGES TRAHUSFABRIKANTERS RIKSFORBUND (STR)
SOLAR ENERGY BUILDING IN VETLANDA
(PASSIVE SYSTEM)

The project is conducted under the auspices of STR – the National Association of Swedish Wooden House Manufacturers – and has been designed by professors Bo Adamson and Bengt Hidemark. The building will be completed in 1976.

I. GENERAL DESCRIPTION OF SYSTEM, PROJECT AND ENVIRONMENT

I.A Objective of Project

The aim has been to create a low-energy building using techniques known today, generally available components and an architectural design consistent with energy conservation. *(Figs. 2, 3,* and *4)*

Solar heating is provided by the windows in the southern facade. Too high inside temperatures are avoided by means of room thermostats, a variable air flow and a fixed solar screening. Heat losses are reduced by means of effective insulation (190 mm in walls and 300 mm in roofs), four-pane-windows with fixed insulation and massive construction. Measurements will be carried out in the STR building and in a reference building during the heating seasons 1976/77 and 1977/78. During 1976/77 the building will be unoccupied.

I.B Description of the Environment

Location

Mamsellvägen, Vetlanda, at 57° 25′ N latitude, 15° 5′ E longitude, about 35 m to the nearest building to the south.

Contact persons: Bo Adamson, Lund Institute of Technology
Bengt Hidemark, Royal Institute of Technology, Stockholm

Climate

The type of climate according to the Trewartha classification is: Dbf. Snow is frequent during winter. Humidity varies between 70 and 90% with a peak during the winter months. Other climatic data are shown in *Fig. 1.*

I.C Description of the Entire System

Description of building

The building (*Fig. 2*) has a girder framework and a concrete slab foundation. Structural units are prefabricated. In order to avoid cold floors and to reduce heat losses the concrete base is laid on 120 mm insulation and surrounded by a heat-insulation foundation wall. The four-pane-windows facing south (*Fig. 3*) are non-opening and of insulating glass type. The other windows can be opened and are triple-glazed. The building floor area is 120 m^2.

Description of installed system

- Passive solar heating system

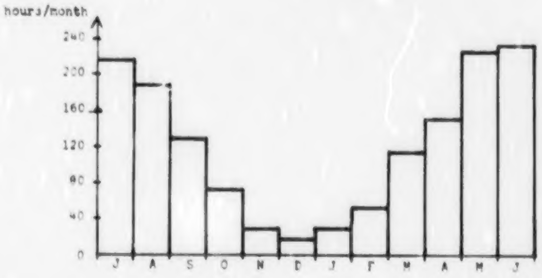
18 m^2 of the facade facing south is provided with four window-panes *(Fig. 3)*. When the inside temperature rises because of solar radiation the thermostats switch off the electric radiators. The extended roof overhang screens off solar radiation in summer-time but not in winter-time.

- Ventilation system

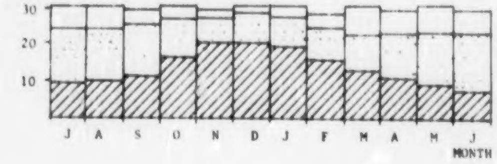
The building is provided with a supply and exhaust air system with a variable flow *(Fig. 4)*. Outdoor air is sucked in below the outer roof in order to utilize the energy from the roofing sheet heated by the sun. The air is preheated and is blown into the building via supply air devices in the floor at the east and south elevations. The evacuation of air takes place above the stove, in the bathroom and toilets. The unintentional ventilation is 0.1 air changes per hour. Normally the ventilation is 100 m^3/h and it may be increased to 250 m^3/h in case of stale air or too high temperatures.

II.A **System Thermal Performance**

System thermal performance is summarized in *Fig. 5* and *Table 1*. The most serious problem with this project could be high indoor temperatures, because of the large south facing glass screening. The roof overhang towards south probably explains why no extreme temperatures have been reported during the summer of 1976.

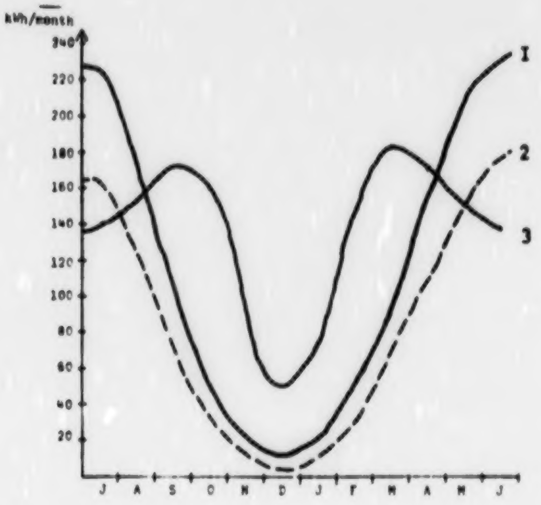


Sunshine hours 1931-60 in Jonkoping.
70 km NW Vetlanda.

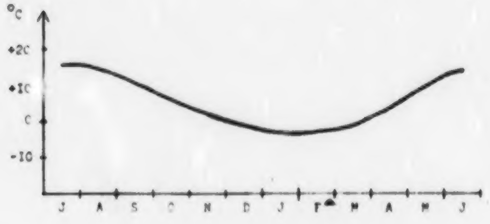


Clear and cloudy days/months.

▨ cloudy ☐ clear

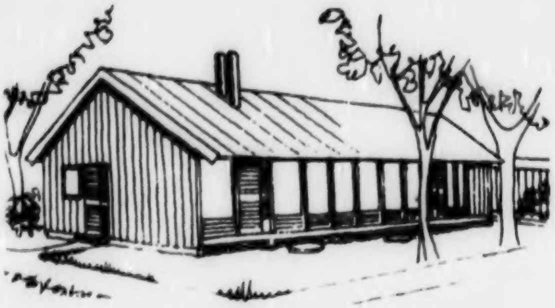


1. Solar radiation a clear day on a horizontal surface
2. Total radiation on a horizontal surface, mean value 1958-69.
3. Solar radiation on a clear day on a vertical south facing surface.
The radiation is valid for Stockholm, 275 km NE Vetlanda.



Average temperature 1931-60.
50 km W Vetlanda.

Figure 1. CLIMATIC DATA



Perspective drawing from SW

Plan

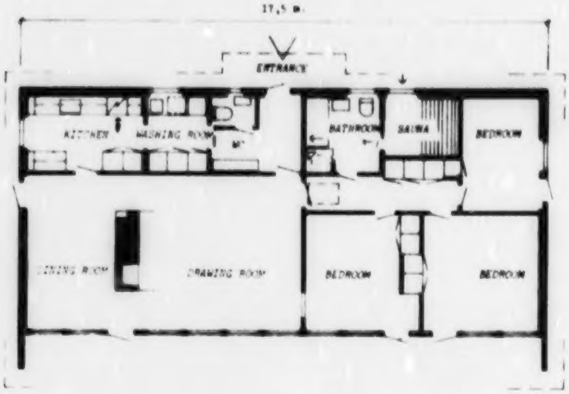
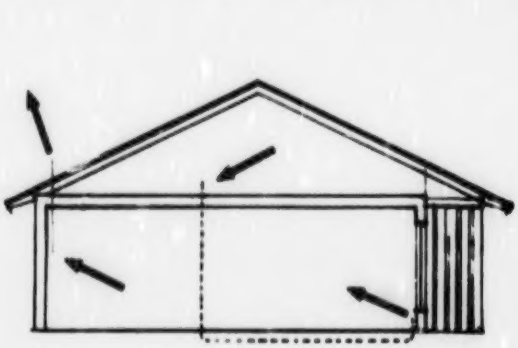

17,5 m.
ENTRANCE
KITCHEN
WASHING ROOM
WC
BATHROOM
SAUNA
BEDROOM
DINING ROOM
DRAWING ROOM
BEDROOM
BEDROOM

Figure 2. **STR HOUSE**

Figure 3. **PASSIVE SOLAR HEATING SYSTEM**



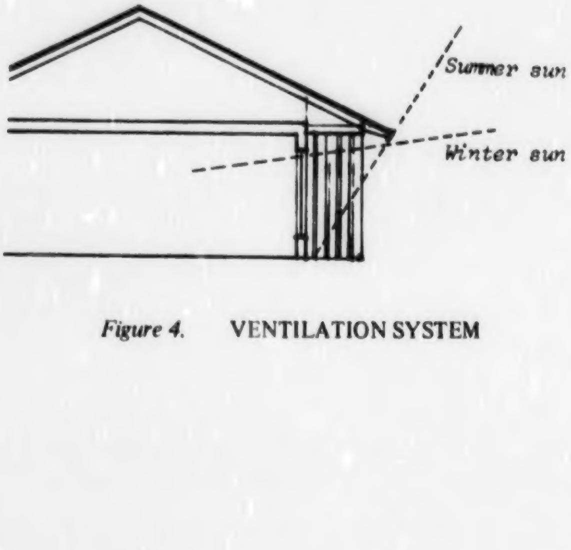
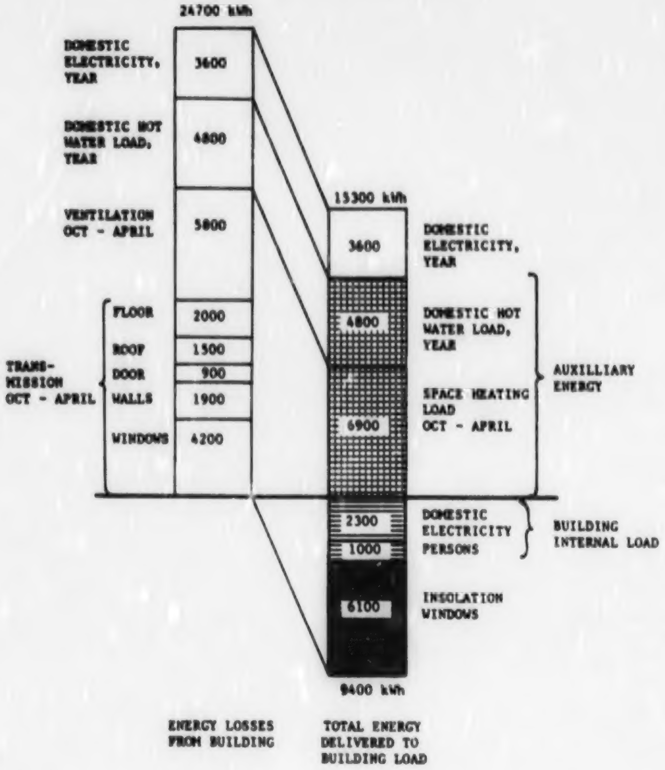
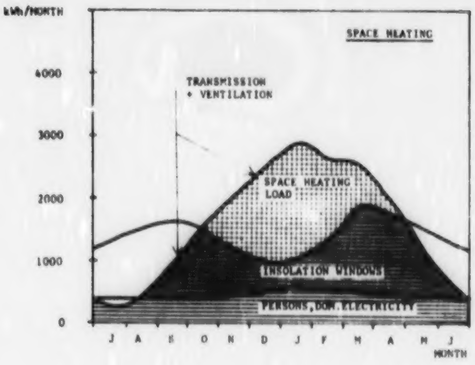

Summer sun
Winter sun

Figure 4. **VENTILATION SYSTEM**

Calculated Energy Balance per Year


24700 kWh
DOMESTIC ELECTRICITY, YEAR
3600
DOMESTIC HOT WATER LOAD, YEAR
4800
VENTILATION OCT - APRIL
5800
TRANS-MISSION OCT - APRIL
FLOOR
2000
ROOF
1500
DOOR
900
WALLS
1900
WINDOWS
4200
15300 kWh
3600
DOMESTIC ELECTRICITY, YEAR
4800
DOMESTIC HOT WATER LOAD, YEAR
6900
SPACE HEATING LOAD OCT - APRIL
AUXILLIARY ENERGY
2300
DOMESTIC ELECTRICITY
1000
PERSONS
BUILDING INTERNAL LOAD
6100
INSOLATION WINDOWS
9400 kWh
ENERGY LOSSES FROM BUILDING
TOTAL ENERGY DELIVERED TO BUILDING LOAD

Calculated Energy Balance per Month



Calculated Solar Energy Gain and Heat Losses through South Facing Windows

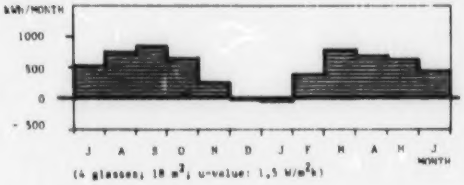


Figure 5. SYSTEM THERMAL PERFORMANCE

Table 1. SPACE HEATING LOAD kWh (Calculated figures)

PERIOD	CLIMATE					TRANS-MISSION LOSSES	VENTI-LATION LOSSES	TOTAL BUILDING INTERNAL LOAD				SOLAR HEAT THROUGH WINDOWS TOWARDS					SPACE HEATING LOAD
	Q	SOLAR ENERGY INCIDENT ON															
		FACADE TOWARDS	FACADE TOWARDS	FACADE TOWARDS	FACADE TOWARDS			PERSONS	DOMESTIC HOT WATER	DOMESTIC ELECTRI-CITY	SOLAR ENERGY SYSTEM (LOSSES)						
	°Ch	N	E	S	W	Q 622	Q 621	Q 652	Q 350 + Q 351	Q 651	Q 255 5	N	E	S	W	TO-TAL Q650	
July	1600	602	1207	1123	1207	175	96	150		250		58	72	621	72	823	0
Aug	2500	372	986	1149	986	274	151	150		250		36	59	854	59	1008	0
Sept	6600	201	665	1105	665	612	337	150		300		21	40	1051	40	1152	0
Oct	9600	111	355	867	355	1050	578	150		300		11	21	972	21	1025	153
Nov	12400	45	138	504	138	1357	746	150		350		5	7	583	7	602	1001
Dec	14800	26	85	427	85	1619	891	150		350		3	5	405	5	418	1592
Jan	17000	32	103	451	103	1860	1023	150		350		3	7	518	7	535	1848
Feb	15600	75	242	708	242	1696	933	150		350		8	14	855	14	891	1238
March	15400	171	593	1192	593	1685	927	150		300		18	35	1296	35	1384	778
April	11200	282	873	1165	873	1225	674	150		300		28	52	1080	52	1212	237
May	7400	522	1210	1231	1210	810	445	150		250		50	73	900	73	1096	0
June	3700	642	1196	1060	1196	405	223	150		250		63	72	576	72	783	0
Sum						12764	7024	1800		3600						10929	6847

UNITED STATES:
SUMMARY OF 1976 SPECIAL FORMAT REPORTS

Redfield W. Allen
Dept. of Mechanical Engineering
University of Maryland

During the present year (1976), United States researchers have prepared seven Special Format Reports on solar heating systems, on solar heating and cooling systems, on a solar assisted heat pump system, and on a solar domestic and an industrial hot water heating system (References 1-7). The CCMS Projects Office of the Mechanical Engineering Department of the University of Maryland has provided assistance to the preparers in interpreting the System Reporting Format and has handled the printing and distribution of the reports. Each Special Format Report was prepared by a project contractor group. The types of projects covered by the seven Special Format Reports, together with the project contractors may be categorized as follows:

(1) **Industrial**. Large scale application of solar hot water heating for an industrial process.
Lawrence Livermore Laboratory

(2) **Schools**. Two with solar heating systems and one with a combined heating and cooling system. Installations retrofitted on existing buildings:

Honeywell, Inc.
General Electric Co.
Westinghouse Electric Corp.

(3) **Residences**. One solar heated and cooled, and one with solar assisted heat pump system. Systems installed during construction of dwellings

Colorado State University
Kaman Sciences Corp./City of Colorado Springs

(4) **Apartments**. Solar domestic hot water heating systems for two apartment complexes. Installations retrofitted on existing buildings.

Southern California Gas Co./Jet Propulsion Laboratory

The Special Format Reports prepared for the United States projects varied in length from 35 to 116 pages, the average length being about 55 pages. Preparers commented that the questions posed by the System Reporting Format were very comprehensive and that preparation of each report required an in-depth review of the project.

This summary report adheres to the order cited in the first paragraph. First, a detailed summary of the industrial hot water system Special Format Report is given. This is then followed by a combined and condensed summary of the reports on the three school systems. Next, a combined and condensed summary of the reports for the two residential systems is given together with a summary of the report on the apartment domestic hot water system.

PERFORMANCE OF THE SOHIO SOLAR WATER HEATING SYSTEM USING LARGE AREA PLASTIC COLLECTORS (GRANTS, NEW MEXICO)

Prepared by
Lawrence Livermore Laboratory

I. GENERAL DESCRIPTION OF SYSTEM PROJECT AND ENVIRONMENT

A. Objective of Project

To design and build a system of shallow solar ponds (SSPs) to provide approximately 50% of the hot water required to accelerate the chemical leaching process at a uranium mining and milling complex in the southwest United States.

B. Description of the Environment

1. Climate

Semiarid continental type: BS-BW on the Trewartha worldwide classification system. Average annual rainfall 197 mm. Annual average snowfall is 264 mm, sunshine hours annual average 78%.

2. Location

State of New Mexico: 35.1°N latitude, 107.8°W longitude, altitude 1830 m.

3. Solar Radiation

The mean monthly total insolation on a horizontal surface varies from 30 MJ/m^2 day in June to 10 MJ/m^2 day in December (See also *Fig. 2*).

4. Ambient Temperature

Mean dry bulb 10°C, average relative humidity is 32%.

5. Wind

Surface wind speeds average 4 m/s.

C. Description of System

1. Qualitative Description

Shallow solar ponds (SSPs) are glazed horizontal flat plate collectors. Each morning cold water is pumped into the shallow pond collector and each afternoon the hot water is removed.

Three of the proposed 72 SSP modules have been constructed, together with a cold water reservoir and a hot water reservoir.

2. Quantitative Description

The shallow solar pond system includes 3 SSP modules, each 3.5 m x 60 m ($210 m^2$), a $100 m^3$ cold water reservoir and a $100 m^3$ hot water reservoir. An SSP module consists of a prefabricated polyvinylchloride (PVC) bag. The bottom layer is 0.5 mm black PVC and the evaporation suppression layer is 0.3 mm clear PVC. Concrete curbs provide vertical elevation for an additional layer of curved glazing panels, *Fig. 1*.

Bottom insulation is a 3.8 cm slab of foamed glass. The top glazing is a 0.9 mm corrugated clear fiberglass with a UV absorbing Tedlar bonded surface. The collector optical efficiency is 75% and the collector loss coefficient is $7.3 W/m^2 {}^\circ C$. The capacity of an SSP module is 25 kg of water. One to two hours is required for the filling and emptying process. Water is pumped in at sunrise and out three hours before sunset.

II. SYSTEM THERMAL PERFORMANCE

A. Daily, Monthly and Annual Values of the Mean Daily Quantities

Figure 2 shows the monthly average values of daily total radiation on a horizontal surface as measured with an Eppley pyranometer at the Sohio plant site during 1975. Also shown is the daily heat collected and the monthly supplemental energy required.

B. Record of the Quality of Thermal Performance of the System

The monthly calculated collected heat is shown in *Fig. 3* for morning water temperatures of 15° and 25°C. The average temperature of the well water used for daily filling of the SSPs at the site is expected to be about 15°C; hence it can be expected that the annual collection efficiency will be about 45 to 50%.

C. Solar Contribution to Energy Requirements

See *Fig. 2*. The total heat collected over 9 months is only about 10% less than that collected over the 12 month period. Because of snow and cold weather at the site during the 3 winter months, it may not be worth the additional operation and maintenance costs to operate the SSPs.

D. Monthly and Annual Energy or Fuel Savings

The average annual solar energy collected by the proposed 72 module SSP system would be 52,500 GJ. Fuel oil contains 6.1 GJ per barrel and if it is converted in the oil boilers with a conversion efficiency of 70%, the collected energy represents an annual fuel oil savings of about 12,000 barrels (i.e. 0.8 barrels s/m^2 collector area).

III. SYSTEM ECONOMIC ANALYSIS

Projected costs for 72 module SSP system:

	$/m²
(1) Site Preparation	$ 6.70
(2) Collectors	
Materials	26.76
Installation	3.90
(3) Hot water reservoir	$6.43
(4) Pumping stations	2.14
(5) Piping	4.45
(6) Hot water pipe to mill	2.46
(7) Controls and electrical	1.30
	$54.14/m² Total

Economic Study Assumptions:

Average annual contribution of solar heat, % of total	50%
Delivered price of fuel oil	0.095$/liter
Per year increase in oil price	5%
Conversion efficiency of fuel oil to usable heat	70%
Annual Operation and Maintenance (no solar)	1.3$/m²
Annual Operation and Maintenance (with solar)	1.95$/m²
Required after tax rate of return on investment	8%
Investment tax credit	7%
Industrial income tax rate	50%
Salvage value for solar system	0

Overall cost of process heat under various conditions. All Calculations made in dollars of uniform purchasing power (1976 dollars):

Heating Mode	Solar System Lifetime (Years)	Life Cycle Cost ($/GJ)
100% fuel oil	-	4.78
50% oil, 50% solar	15	4.25
50% oil, 50% solar	20	4.21

Payback period on 54.14 $/m^2 investment:

Including income tax on cash savings	7.2 years
No income tax on cash savings	4.8 years

SUB-SYSTEM PERFORMANCE

A. Solar Collectors

A.1 Description of Physical Configuration

See *Fig. 1*.

A.2 Thermal Performance Characteristics

SSP performance at solar noon on several days in July:

Optical efficiency	0.75
Thermal loss coefficient	$7.3W/m^{2\circ}K$

B. Thermal Energy Storage Subsystem

Storage pond performance not reported.

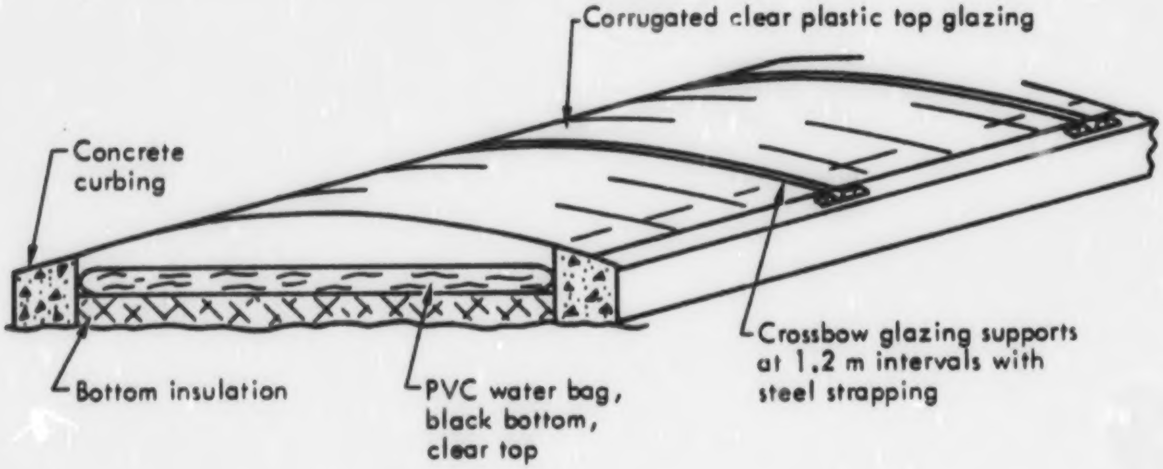

Corrugated clear plastic top glazing
Concrete curbing
Bottom insulation
PVC water bag, black bottom, clear top
Crossbow glazing supports at 1.2 m intervals with steel strapping

Figure 1. Short length of a shoallow solar pond module. A full-sized module is typically 3.5 m x 60 m.

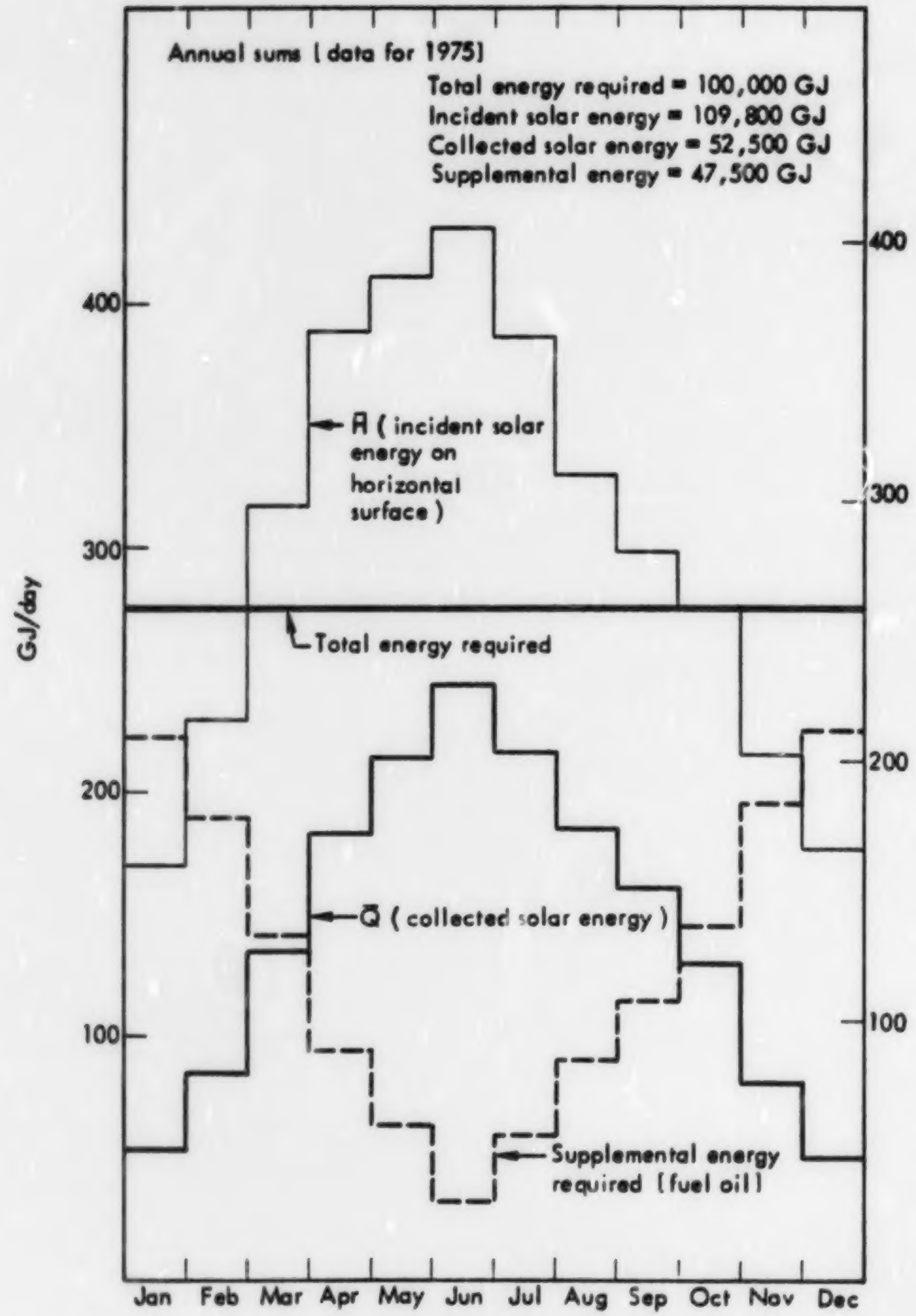


Figure 2. Monthly average values (for 1975) of daily total radiation, daily energy required by uranium mill, daily solar heat collected, and daily supplemental heat required by the mill.

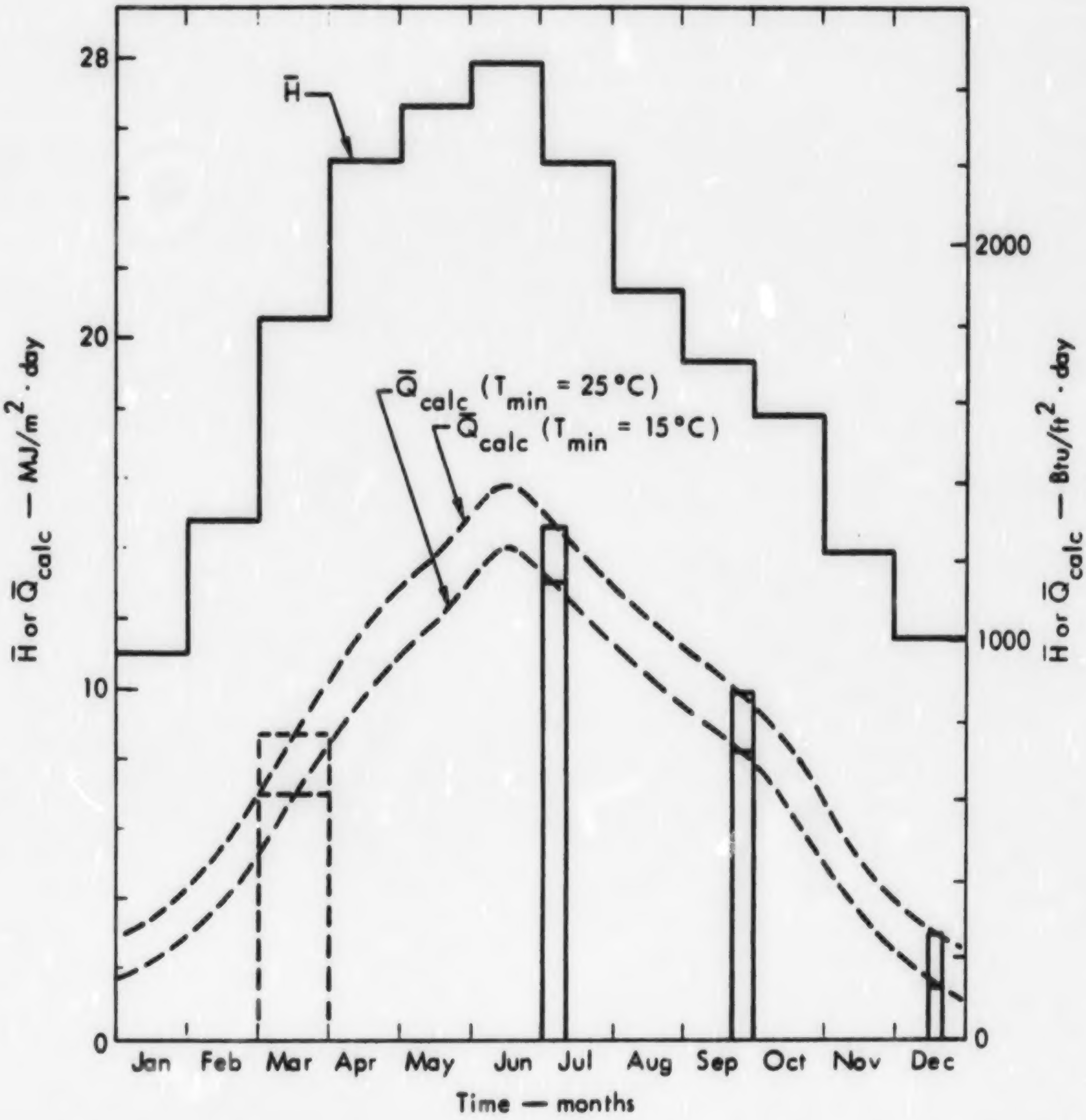


Figure 3. Values for 1975 of $\bar{Q}_{calc}$ (useful heat) at T_{min} = 15° and 25°C for SSP's. Also shown are 1975 measured values of $\bar{H}$ (monthly average daily total insolation on a horizontal surface).

SUMMARY OF U.S. SCHOOL PROJECTS SPECIAL FORMAT REPORTS

Three school projects were sponsored by the United States Government in order to demonstrate large-scale applications of solar space/hot water heated and solar actuated cooling (References 2, 3, 4). As indicated by the columns in *Table 2*, school sites at Atlanta, Boston, and Minneapolis were chosen to demonstrate space/hot water heating and cooling (H/HW&C), space heating (H) and space/hot water/swimming pool heating (H&HW), respectively. Locations ranged from Atlanta in the southeast U.S. at 34 deg. N latitude to Minneapolis in the upper midwest U.S. at latitude 45 deg. N. with corresponding heating degree (C) days ranging from 1720 to 4500. The solar heating/cooling systems (*Figure 4 a, b, c*) employed flat plate solar collectors in saw tooth arrays on roof-mounted trusses retrofitted to existing school structures. The Atlanta collector installation included reflector arrays to boost the output of the collectors during the summer when the absorption air conditioning machine (175 kw cooling rate) was being operated. Collector slopes were equal to – or somewhat greater than – latitude, and areas ranged from 426 m^2 to 1005 m^2, *Table 2*. The Atlanta system employed the largest ratio of storage volume to collector area. The storage tank was buried adjacent to the building. The other installations were constrained in this respect in that indoor tanks of limited size were used.

The thermal performance of the three school systems is summarized in *Table 3*. Some items were not available and are omitted. The row entitled "Solar energy used" shows the greatest energy use (2.2 GJ/m^2 collector area) was reported for the Atlanta system which heated space, heated domestic hot water, and provided air conditioning. Next in order was the useful energy collected by the Minneapolis installation (1.5 GJ/m^2 collector area) which provided space heating, domestic hot water, and swimming pool heating. Collection "efficiencies" for the three systems are reported in *Table 2*, first for the inclusive hours of collector coolant pump operation only, and second for all daylight hours. The latter efficiency is low (e.g. 30% compared to 43%, for Minneapolis) because it includes the zero utilization factor for the daylight hours during which the collector was not supplying hot water. Thus the system which provided space heating only, and therefore had a low overall utilization factor, yielded a low collection efficiency based on all daylight hours (i.e. Boston, 18%).

The retrofit demonstration solar heating (or heating and cooling) systems installed in the three schools were one-of-a-kind systems, designed and fabricated without benefit of mass production techniques and large sales volumes to carry engineering costs. Contractors who bid on the jobs had no prior experience and were, therefore, likely to have submitted high bids to cover contingencies. Viewed in this perspective, the economic section, *Table 4*, of this summary, provides an interesting comparison of costs broken down in accordance with the System Reporting Format. Total design and installation costs ranged between 500 and 600 $/$m^2$ with collectors accounting for as low as 13% of system cost. On-site labor costs were in the neighborhood of 10 to 20% of system cost.

Solar Heating and Cooling System

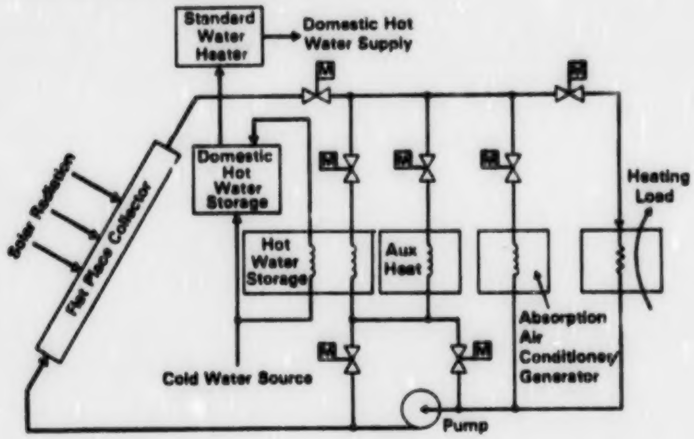

Standard Water Heater
Domestic Hot Water Supply
M
M
Domestic Hot Water Storage
M
M
M
Heating Load
Solar Radiation
Flat Plate Collector
Hot Water Storage
Aux Heat
Absorption Air Conditioner/ Generator
M
M
Cold Water Source
Pump

Figure 4a.
Alanta System

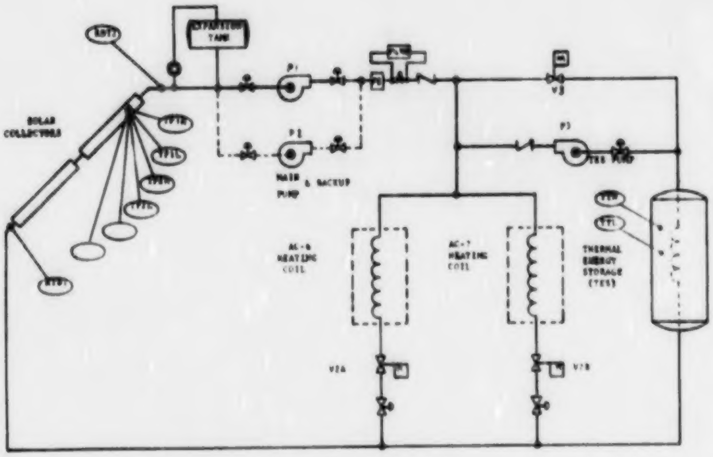

EXPANSION TANK
P1
SOLAR COLLECTORS
P2
MAIN PUMP
& BACKUP
V3
P3
TES PUMP
AC-6 HEATING COIL
AC-7 HEATING COIL
THERMAL ENERGY STORAGE (TES)
V2A
V2B

Figure 4b.
Boston System

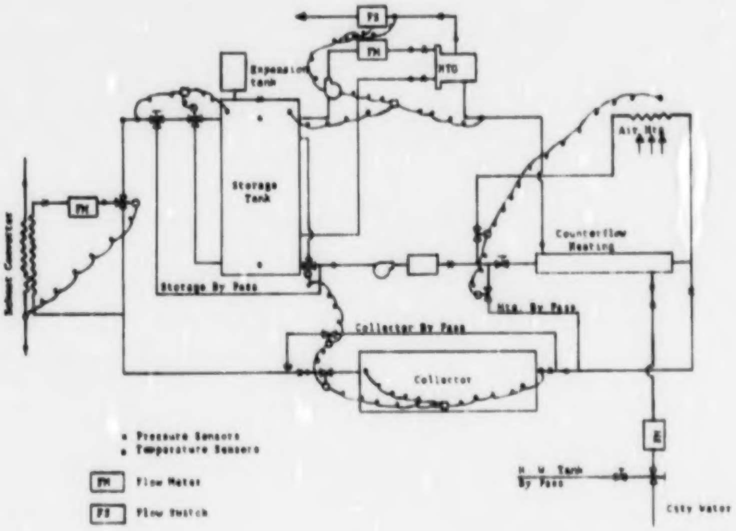

FS
FM
Expansion tank
HTG
Air Htg
Storage Tank
FM
Solar Collector
Counterflow Heating
Storage By Pass
Htg. By Pass
Collector By Pass
Collector
E
Pressure Sensors
Temperature Sensors
FM Flow Meter
FS Flow Switch
H W Tank By Pass
City Water

Figure 4c.
Minneapolis System

Table 2

SUMMARY OF OBJECTIVE, ENVIRONMENT AND SYSTEM DESCRIPTION FOR THE THREE U.S. SCHOOLS

	ATLANTA	BOSTON	MINNEAPOLIS
OBJECTIVE			
Heating (H)	Demonstration of H, HW, & C	Demonstration of H	Demonstration of H & HW
Cooling (C)			
Hot water (HW)			
ENVIRONMENT			
Climate	Subtropical humid	Humid continental	Continental
Latitude, deg. N	34	42	45
Heating, deg. C days	1720	3120	4500
Cooling, deg. C days	880	370	585
Annual solar radiation on collector (GJ/m^2)	6.9	5.1	7.7
SYSTEM			
Collector type	Flat plate two glass covers alum. absorber	Flat plate two plastic covers alum. absorber	Flat plate two covers steel absorber
Reflector	Yes	No	No
Collector array	Sawtooth	Sawtooth	Sawtooth
Collector slope (deg)	35	45	55
Collector area (m^2)	1005	426	465
Fluids	Water-nitrogen (draindown)	Water-glycol	Water-glycol

Table 3

SUMMARY OF SYSTEM THERMAL PERFORMANCE - ANNUAL VALUES FOR THE THREE U.S. SCHOOLS

	ATLANTA	BOSTON	MINNEAPOLIS
Heating load (GJ/m^2) (a)	3.1	0.94	-
Cooling load (GJ/m^2)	2.9	-	-
Supplemental energy (GJ/m^2)	-	-	-
Annual insolation (GJ/m^2)	6.9	5.1	7.7
Solar energy collected	-	-	-
Solar energy used (GJ/m^2)	2.2	0.44	1.5
Heating % solar	50	47	54
Cooling % solar	60	0	0
Domestic Hot Water % solar	80	0	21
Collection efficiency (b)	-	0.50	0.43
Collection efficiency (c)	-	0.18 (d)	0.30
Annual fuel savings ($/m^2)	-	5 (electric)	-

Notes:
(a) Collector area
(b) Hours of collector pump operation only.
(c) All daylight hours.
(d) September through May.

Table 4

SUMMARY OF SYSTEM ECONOMIC ANALYSIS FOR THE THREE U.S. SCHOOLS

(Costs in $/m^2 collector)

	ATLANTA	BOSTON	MINNEAPOLIS
Design (D)	64	16	-
Installation (I)	441	463	532
Total D & I	505	579	-
Labor (L)	214	143	77
Materials (M)	227	320	455
Total L & M	441	463	532
Collector	66	163	212
Annual Operating	0.7	2	–

SUMMARY OF THE COLORADO STATE UNIVERSITY HOUSE I, PHOENIX HOUSE PROJECT, AND APARTMENT HOT WATER SYSTEM SPECIAL FORMAT REPORTS

The two residential solar projects in Colorado, the Colorado State University (CSU) Solar House I and the Phoenix House Project in Colorado Springs (CS) (References 5 & 6), had the objectives of design, construction and evaluation of practical systems for utilizing solar energy to drive heating, cooling, and domestic hot water systems (CSU) or to work in conjunction with large storage and a heat pump (CS). The environment, *Table 5*, is dry with a relatively long heating season and moderate air conditioning needs. A shallower slope of the two-cover flat plate collector array is shown in *Table 5* for the combined heating/cooling system (CSU). The larger storage of the heat pump system (CS) was to provide heat input to the heat pump for an extensive period. The two residential systems had similar collector areas and both systems provided domestic hot water.

The annual system thermal performance results, *Table 6*, show a seasonal heating load of 0.48 GJ/m^2 (collector area) for CSU House I, of which 87% was supplied by the solar heating system. The seasonal hot water heating load was quite high at 0.43 GJ/m^2, with 49% being supplied solar energy. Heat actuated absorption cooling for CSU House I accounted for the largest annual heat requirement, 0.72 GJ/m^2, 81% of which was supplied by the solar collection/storage system and at temperatures in the 90°C range. The aggregate annual energy saving for this system was 1.15GJ/m^2 (collector area).

The Colorado Springs House had a seasonal heating load of 1.66GJ/m^2, 70% of which was supplied by the solar heating system. By operating the heat pump in the solar assisted mode using stored heat, the heating coefficient of performance was maintained at the relatively high level of 2.9, according to the report.

The economics of the two residential systems is included in *Table 6*. Reported costs for these systems, at 142 and 177 \$/m^2 were considerable less than those reported for the school systems, due in part to the fact that the residences were new construction. It will be noted that no design charges were made against the Colorado Spring house. The detailed assumptions may be found in the printed reports.

The reports on both residential systems contain much information on the subsystems and on the control modes under which the systems were tested. It should be noted that the test year for these residences included operation in control modes that were later found to be non-ideal. In future years, therefore, the systems may be expected to yield a higher level of performance.

The characteristics of the apartment hot water system (Project Sage), erected in California, is summarized in the third column of *Tables 5* and *6*. The collector sawtooth array was retrofitted to an existing apartment building by adding a truss structure and the necessary piping connections. A collector slope of latitude plus 19° was used to boost winter collection. Tanks and pumps were installed in basement spaces. The 94 m^2 collector array supplied 83% of the 3.01 GJ/m^2 annual hot water heating load at an annual collection efficiency of 40%. The total cost of this retrofitted installation, 510 \$/m^2, is comparable to the retrofitted school installations.

Table 5

SUMMARY OF OBJECTIVE, ENVIRONMENT, AND SYSTEM DESCRIPTION FOR TWO HOUSE PROJECTS AND AN APARTMENT HOT WATER PROJECT

	CSU HOUSE I	COLORADO SPRINGS HOUSE	APARTMENT HOT WATER SYSTEM
OBJECTIVE			
Heating (H)	Experimental Studies in H, HW, & C	Experimental Studies in H, HW, HP	Demonstration of HW
Hot water (HW)			
Cooling (C)			
Heat Pump (HP)			
ENVIRONMENT			
Climate	cold, semi-arid	cold, semi-arid	subtropical
Latitude, deg N	41	40	34
Heating deg.-days	3300	3600	960
Annual Insolation (GJ/m^2)	6	3.45* *Oct.-May	6.1 (horiz.)
SYSTEM			
Residence floor area (m^2)	140	195	N.A.$^{(a)}$
Heated basement	yes	yes	N.A.
Design heating load at 23°C (kw)	16.1	-	N.A.
Design cooling load (kw)	10.5	N.A.	N.A.
Collector area (m^2)	71.4	72.5	94
Collector slope (deg)	45	55	53
Collector covers (no.)	2	2	2
Collector abs. plate	AL	AL	Cu
Collector fluid	water	Dowtherm J	water (inhibited)
Storage tank (m^3)	4.3	30	4.6
Storage tank location	basement	buried	basement
Storage fluid	water	water	water
Domestic preheat tank	yes	no	yes
Air conditioner	yes	no	N.A.

Note: (a) Not applicable

Table 6

SUMMARY OF ANNUAL SYSTEM THERMAL PERFORMANCE AND ECONOMICS FOR TWO HOUSE PROJECTS AND AN APARTMENT HOT WATER PROJECT

	CSU HOUSE I	COLORADO SPRINGS HOUSE	APARTMENT HOT WATER
ANNUAL SYSTEM THERMAL PERFORMANCE (a)			
Heating load (GJ/m^2)	0.48	1.66	N.A.
Hot water load (GJ/m^2)	0.43	-	3.01
Heat to A/C (GJ/m^2)	0.72	N.A.	N.A.
Incident solar heat (GJ/m^2)	6.01	3.45 (Oct-May)	5.7
Solar heat to space (GJ/m^2)	0.36	1.21	N.A.
Solar heat to HW (GJ/m^2)	0.18	included above	2.5
Solar heat to A/C (GJ/m^2)	0.20	N.A.	N.A.
Total solar heat used (GJ/m^2)	0.74	1.21	2.5
Solar contribution (%)			
Heating	87	70	N.A.
HW	49	-	83
Cooling	81	N.A.	N.A.
Annual energy savings (GJ/m^2)	1.15	1.0	-
ECONOMICS (\$/m^2)			
Design (D)	-	0	51
Installation (I)	-	177	459
Total D & I	142	177	510
Labor (L)	52	45	30
Material (M)	90	132	-
Total L & M	142	177	-
Collectors	-	-	100
Annual operating	1.8	4	-

Note: (a) m^2 denotes collector area

REFERENCES

(1) *U.S. Special Format Report: Performance of the Sohio Solar Water Heating System Using Large Area Plastic Collectors*, Lawrence Livermore Laboratory, May 1976, SAN/1038-76/1.

(2) *U.S. Special Format Report: Northview Junior High Solar Energy School Heating Augmentation Experiment*, Honeywell Systems and Research Center, June 1976, COO/2624-77/1.

(3) *U.S. Special Format Report: Report on the Grover Cleveland School Solar Heating System, Boston, Massachusetts*, General Electric Company, August 1976, COO/2626-76/1.

(4) *U.S. Special Format Report: Report of the George A. Towns Elementary School Solar Heating and Cooling Project, Atlanta, Georgia*, Westinghouse Electric Corp., July 1976, COO/2628-76/1.

(5) *U.S. Special Format Report: Design, Construction and Testing of the Colorado State University Solar House I Heating and Cooling System*, Colorado State University, June 1976, COO/2577-76/1.

(6) *U.S. Special Format Report: Report of the Phoenix Corporation-City of Colorado Springs Solar Heating Project*, Kaman Sciences Corp., June 1976, WA/4578-76/1.

(7) *U.S. Special Format Report: Project Sage Solar Assisted Gas Energy Project*, Southern California Gas Co., August 1976, SE/4691-76/1.

V. PROJECTS FOR WHICH SPECIAL FORMAT REPORTS WILL BE PREPARED DURING 1977

INTRODUCTION

The second round of exchange of Special Format Reports was initiated at the 1976 Copenhagen meeting with a session devoted to descriptions of projects for which Format Reports will be prepared during 1977. A significant increase was noted both in the number of countries which plan to prepare such reports and in the total number of reports anticipated. Summaries of the system projects to be reported on in this exchange are given in this section of the annual report.

SUMMARY

In the period between the 1976 CCMS meeting in Copenhagen, Denmark and the next meeting in the Federal Republic of Germany, participating countries will prepare 44 Special Format Reports. These projects are listed in *Table 1*. There will be reports on several large domestic hot water heating systems and an industrial process (can washing) hot water system (Australia). Other industrial processes to be reported will include peanut drying, grain drying, lumber drying and commercial greenhouse heating (U.S.). Passively heated and low-energy dwellings will continue to receive attention (Canada, Denmark, The Netherlands, Sweden, U.S.). The number of annual thermal energy storage systems will be increased above the first round (Canada, Denmark, FRG, U.S.). Heat pumps will be included in a few systems (Canada, U.S.). Solar space heating via hot water systems will be involved in the majority of the systems to be reported in 1977. Some of these systems installed in the U.S. will include solar actuated air conditioning. Solar space heating via air systems (not counting passive systems) will be in the minority.

Table 1

SYSTEM PROJECTS PROPOSED FOR SPECIAL FORMAT REPORTS DURING 1977

COUNTRY	PROJECTS
AUSTRALIA	Final Report on Hot Water System for CSIRO Phytotron (Canberra). Final Report on Hot Water System for Sacred Heart College (Adelaide). Final Report on Somers Yacht Club Hot Water System. Industrial Process Heating Installation at a soft-drink plant (Queanbeyan, New South Wales). Performance of several residential hot water systems (Northern Territory).
BELGIUM	Comparison between modelisation and measurements on collectors. System description of a solar heated house.
CANADA	Performance of the Mississauga House solar heating system using heat pump (Toronto). Performance of the Provident House solar heating system using seasonal energy storage (Toronto). Performance of the NRC and HUDAC solar heated house (Ottawa). Performance solar heated senior citizens home, Aylmer (Ontario). Performance Stanley-Jones residence solar heating system (Ottawa).
DENMARK	Performance of the zero energy house solar heating system (Lyngby). Performance of the solar heating system for the Danish Boiler Owner Association office building (Aalborg, Jutland). Subsystem performance of three air collectors.
FEDERAL REPUBLIC OF GERMANY	Performance of the solar heating system for a private residence (Deizisau). Performance of the solar heating system of the MBB Solar House I (Höhenbirchen).
FRANCE	Performance of solar heated houses using Liebard run-off collectors (Blagnac). Performance of the solar heating system for low-income apartments (housset, Bouches-du-Rhône). Performance of five solar houses using Roll-Bond collectors (Aramon, Gard). Performance of 5 solar houses in a housing development, using Roll-Bond collectors (Le Havre). Performance of the solar heating system for the student center at the National School of Mines, Alès. Performance of the solar heating installation at the Internal Revenue Building, Salon.
GREECE	Performance of the solar heating system for a portion of an office building (Athens).
THE NETHERLANDS	Performance of the solar heating system of an energy saving dwelling (Oss). Performance of a solar heated house with a special device to increase stratification (Eindhoven). Performance of a solar heated house (Zoetermeer). Performance of the solar heating system for a laboratory (Enschede).
SWEDEN	Performance of the solar heating system for the low-energy Euroc House (Limhamn). Performance of the solar heating system of the Ostgotabyggen House (Linkoping).

Table 1 (Continued)

COUNTRY	PROJECTS
SWEDEN	Preliminary performance report on the passive solar heating system of the STR House (Vetlanda). Report on the Ostgotabyggen central storage project (Linkoping). Preliminary report on the joint Building Technology-Physical Chemistry Institutions (Technical University of Stockholm) project.
TURKEY	Performance of an as-yet undesignated project.
USA	Solar Heating and Cooling of a City Community Center (Santa Clara, California). Retrofit Heating, Cooling and Hot Water System for an Elementary School (Atlanta, Georgia). Solar Heating and Cooling of an Office/Laboratory (New Mexico). Design of Collectors and Instrumentation for Application to Solar Drying Peanuts (Georgia). Solar Energy Assisted Heat Pump Grain Drying (Illinois). Use of Solar Energy for Poultry House Heating and Manure Drying (Mississippi). Heating Greenhouses with Solar Energy (New Jersey). Evaluation of High Performance Collectors in a Residential Heating and Cooling System (Colorado). Evaluation of a Residential Solar Air Heating System (Colorado). Analysis of a Retrofitted Solar Heated Row Home (Philadelphia, Pennsylvania).

AUSTRALIA: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

R. N. Morse
Commonwealth Scientific and Industrial Research Organization
Solar Energy Studies

FINAL REPORT ON HOT WATER SYSTEM FOR CSIRO PHYTOTRON, CANBERRA

This system has been operating since 1962, and supplies service hot water for a laboratory building. It has collectors with a total area of 30 m^2 coupled to a hot water storage tank of 1800 litres which is fitted with electric elements for supplementary heating.

FINAL REPORT ON HOT WATER SYSTEM FOR SACRED HEART COLLEGE, ADELAIDE

This system has been operating since 1966, and provides service hot water for the dormitory block. It consists of collectors with a total area of 60 m^2 coupled to two 2050 litre hot water storage tanks, with an oil-fired backup boiler which heats one of the tanks through a heat exchanger.

FINAL REPORT ON SOMERS YACHT CLUB HOT WATER SYSTEM

This system was installed in 1975 and supplies hot water to showers and a small kitchen. The collector area is 10 m^2 coupled to a 230 litre, a 460 litre and a 360 litre hot water storage tank connected in series. Electric supplementary heating elements are fitted to the 230 and the 460 litre tanks.

INDUSTRIAL PROCESS HEATING INSTALLATION AT A SOFT-DRINK PLANT, QUENABEYAN, NEW SOUTH WALES

The system is under construction and expected to be operational early in 1977, to supply heat to a can warmer which operates at 60°C. It uses collectors developed for process heating applications with a total area of 77 m^2 coupled to a 20 m^3 prefabricated concrete thermal storage. Supplementary heating will be supplied by the existing oil-fired boiler in the factory. Heat meters will be installed in the collector circuit, the store to can warmer energy transfer loop and in the oil-fired boiler circuit.

RESIDENTIAL HOT WATER SYSTEMS

The performance of several residences will be monitored in the Northern Territory, where government houses have been using solar water heaters since 1959.

BELGIUM: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

A. Pilatte
Faculte Polytechnique De Mons

During the coming year, some aspects of the program, which was described in the national program report, will be studied intensively and we plan to prepare special format reports for next year's meeting. These projects are:

- Results on the comparison between modelisation and measurements on collectors.
- System description of the planned solar heated house.

The Chevetogne project (vacation village and sports center) should be underway next year and if enough information is available, it will be presented at the next meeting.

CANADA: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

J. R. Sasaki
Division of Building Research
National Research Council of Canada

Special format reports will be prepared in 1977 for two solar demonstration houses. (These are the projects for which interim format reports were prepared in 1976.) Pertinent features of the two houses are given in *Table I*.

In addition, three other solar heated buildings will be extensively monitored in the coming year by the NRC. These are the solar-heated house co-sponsored by NRC and the home builders' association of Canada (HUDAC); the 30-unit Senior Citizens Home constructed by the province of Ontario; and a privately-funded home built near Ottawa, identified as the Stanley-Jones residence. These buildings will be instrumented with integrating heat and power meters as well as with a data logging system capable of providing system operation data for validation of building heat-load calculation programs and solar heating system simulation programs. These projects will be reported in the special format in 1978 and are described briefly in *Table II*.

Table I

CANADIAN SOLAR DEMONSTRATION HOUSES TO BE DESCRIBED IN SPECIAL FORMAT REPORTS IN 1977

(1) MISSISSAUGA HOUSE – Toronto, Ontario

Living area = 135 m^2
Collector area = 64.4 m^2 (flat-plate, water-heating collectors; single glazed; selective absorber)
Storage volume = 18 m^3 (water)
Supplementary heat = water-to-air heat pump, and electrical resistance heaters

(2) PROVIDENT HOUSE – Toronto, Ontario

Living area = 248 m^2
Collector area = 66.7 m^2 (flat-plate, water-heating collectors; single glazed; selective absorber)
Storage volume = 274 m^3 (water)
Supplementary heat = none

Table II

CANADIAN SOLAR-HEATED BUILDINGS FOR WHICH SPECIAL FORMAT REPORTS WILL BE PREPARED IN 1978

Identification	Living Area (m^2)	Medium	Collector Area (m^2)	Storage Volume (m^3)
(1) NRC/HUDAC Ottawa, Ontario	110	Air	37	– (rock)
(2) Stanley-Jones house Ottawa, Ontario	172	Water	21.5	22.5 (water)
(3) Senior Citizen Home Aylmer, Ontario	1950	Water	186	900 (water)

DENMARK: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

T. V. Ebensen
Thermal Insulation Laboratory
Technical University of Denmark

SYSTEM PERFORMANCE:

1) Report on the solar heating system of the Zero Energy House at the Technical University.
2) Report on the solar heating system of the 300 m^2 office building at the Danish Boiler Owner Association in Aalborg, Jutland. The solar collector is 70 m^2 , and the storage volume is 45 m^3.

SUBSYSTEM PERFORMANCE:

3) Report on 3 solar air collectors which can be integrated in the roof construction. Blackpainted metal plates are used as absorbers behind which the air is circulated.

FEDERAL REPUBLIC OF GERMANY: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

THE SOLAR HOUSE IN DEIZISAU

G. Lehner
University of Stuttgart

A special Format Report will be prepared on a solar house in Deizisau near Stuttgart, FRG, which has been built on a purely private basis. It is a one-family-house with solar hot water and heating and with an electric back-up-system. The solar system includes:

- 40 m^2 of flat plate collectors
- 2m^3 of short-time water storage (in the basement of the house)
- 70m^3 of seasonal water storage (underground, outside of the house)

The system went into operation between spring and summer of this year. The collector surface is not yet complete, however, 16 m^2 are installed at present. Additional collectors will be put on the garage and in the garden. The water collectors have black painted (non-selective) absorbers based on commercially available very flat heating radiators of steel.

The solar system was planned and built by a private firm and was also financed privately. However, Baden-Württemberg – one of the states of the FRG – has been asked to support a long-term (several years) measurement programme. It was felt that such measurements were in the public interest and support was granted, provided that the University of Stuttgart would prepare, run, and evaluate the measurements.

The measurements have been started this summer (1976). The aim is to arrive at a rather complete energy balance, both solar and electric, over a period of several years. The measurements are restricted to the ones which are inevitably necessary for this purpose, for reasons of cost of both instrumentation and manpower. Thus we will be able to report on the results obtained, which will not, however, cover the entire format developed by the CCMS Solar Energy Pilot Study.

Under German climatic conditions, solar heating requires seasonal storage, which is rather expensive and not economical at present. Thus the project represents an experiment, which should give information of interest for future seasonal storage systems.

PERFORMANCE OF THE MBB – SOLAR HOUSE I

P. Zahn
Messerschmitt-Boelkow-Blohm

The system project which is proposed for a future special format report is the Solar House I of Messerschmidt-Boelkow-Blohm (MBB). It is part of a program for the development of a modular solar heating and cooling system which could be operated in existing or new homes in connection with a conventional fossil-fuel heating system. The program was started in 1974 and is supported by the German Bundesministerium für Forschung und Technologie.

After a period of extended effort in system analysis and component development, MBB has now started a first demonstration system project. Its main objectives are the evaluation of installation procedures, the development of an integrated control method and the gathering of performance data.

The object itself is a typical and unambitious row-house situated in Hohenbirehen near Munich, being fully used by one family. Its annual power demand is about 20 MWh for heating and hot water supply, covered until now by a conventional oil burner. The space heaters are based on hot water circulation.

The roof is south-facing, with a tilt angle of 23. The collector field consists of 35 solar collector modules. There are 9 sets in a series; each set contains 4 modules connected in parallel. The module itself is a standard roof-type flat plate collector which does not employ advanced technology such a selective coatings on IR-absorbers. The water-cooled roll-bond aluminum absorber has an effective area of 1 m^2 and is embedded in an integral polyurethane foam housing. Two glass covers are used. Under zero load with water inventory removed the collector will reach up to 160°.

The integrated solar and fossil heating system will be governed by a common control unit, which designated the mode of operation. All important physical data of the system will be measured continuously.

By September 1976, the installation of all major subsystems had been completed and the total system put into operation.

FRANCE: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS *

J. -P. Marie
Plan-Construction
Ministere de l'Equipement

1. SOLAR-HEATED HOUSES EQUIPPED WITH LIEBARD RUN-OFF COLLECTORS (Under the supervision of the Construction Plan)

This experiment will make it possible to test from the technical and economic point of view three types of solutions on a group of 10 low income housing units at Blagnac:

- Mixed solar-gas heating and hot water heater using run-off collectors (5 houses)
- Gas heating and mixed solar-gas hot water heater (3 houses)
- Gas heating and hot water heater (2 reference houses)

The effectiveness of the Liebard run-off collectors will be assessed in these houses having a unit volume of 250 m^3

- For preheating hot water
- For main heating with gas auxiliary

Fifty percent savings in anticipated for an additional installation cost as compared to the above-mentioned conventional gas option.

2. LOW-INCOME APARTMENTS AT ROUSSET, BOUCHES-DU-RHÔNE (Under the supervision of the Construction Plan)

This experiment involves one of three 32-unit four-story buildings of the same size. One half of the building is entirely heated by electricity, and one-half is heated by solar energy with direct electric auxiliary heating by convectors.

Collection is achieved by 120 m^2 roof collectors and 110 m^2 south wall collectors providing a ratio of 14 m^2 per dwelling. Hot water is distributed by radiant floors. A 15 m^3 storage tank makes it possible to cover the average time lag of the demand and holds a 24-48 hour supply according to the season.

3. "LE PARADIS" SOLAR HOUSES AT ARAMON, GARD (Under the supervision of the EDF-French National Electric Co.)

Five of 15 identical houses used by the staff of the EDF thermal power plant at Aramon were selected for this experiment. Two of them were five-room houses (325 m^3) and three were seven-room houses (376 m^3). All 15 units are "all electric" homes, are heavily insulated, and are equipped with direct electric heating.

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*Translation by U.S. State Dept.

The system tested includes:

- Roll-Bond water heater solar collectors on the south exterior wall (35-38 m^2)
- Basement hot water storage (4 m^3)
- Hot water distribution in ground level slabs
- Auxiliary electric heating by electric convectors with individual thermostats

With the exception of one house which was vacant for about a year, all these buildings are occupied. A measuring device makes it possible to check the temperatures of the heat-bearing fluids at all levels as well as the indoor and out-door ambient temperatures.

Savings in consumption should fall between 55 percent and 65 percent of the energy used for conventional integrated electric heating (heating the premises and hot water supply). This savings will be measured accurately by comparing consumption in the solar-heated houses and in the above-mentioned all-electric houses.

4. SOLAR HOUSES AT LE HAVRE, SEINE-MARITIME (Under the supervision of the EDF- French National Electric Co.)

This operation involves five dwellings in a housing development built by Société HLM du Foyer Havrais (LeHavre Low-Income Housing Company). They have the following characteristics:

- Area: 108 m^2, Volume: 270 m^3;
- Roll-Bond 46 m^2 water heater solar collector, slanted to 61° (latitude + 11° 30′) and 45° 30′;
- 4 m^3 basement hot water storage
- Distribution by ventilation ducts
- Auxiliary electric heating in ventilation ducts

All the EDF systems have been in service since late 1975. Based on the principle of all-electric auxiliary, the comparative Aramon and Le Havre experiments will provide information on potential savings of electric energy in heating for very different climatic conditions.

5. HEATING THE STUDENT CENTER OF THE ECOLE NATIONAL TECHNIQUE DES MINES (National School of Mines) AT ALÈS (Under the supervision of COSTIC)

For an installed 300,000 Kcah/h gas auxiliary and emergency power, the solar installation is composed of:

- 54 m^2 collectors facing south and slanted 60°
- 500 liter reservoir

The carefully studied system includes:

- Regulated collection
- Regulated distribution (direct supply by collectors, supply from storage, recirculation)
- Regulated hot water supply

Numerical computer simulation with Logiciel Helios has made it possible to optimize the collection surface/operating cost ratio. Energy savings on the order of 50 percent are expected.

6. HEATING OF THE INTERNAL REVENUE BUILDING IN SALON (Under the supervision of COSTIC)

Solar heating installations with 315,000 Kcah/h gas auxiliary and emergency power must provide:

- Heating for offices, halls, rest rooms, and file rooms
- Heating of living quarters

The solar installations must include:

- 342 m^2 roof solar collectors
- Basement storage of 5,000 liters (95°C)
- Freeze protection by recirculation
- The system switches to auxiliary power as soon as the storage tank output temperature drops below 60°C

The experiments described herein were conducted prior to the 1976 1977 winter and will have been subject to at least one series of measurements in the heating season prior to their presentation to CCMS in 1977.

RAPPORTS SELON FORMAT
DEVANT ETRE PRESENTES PAR LA FRANCE EN 1977

J. -P. Marie
Plan-Construction
Ministere de l'Equipement

Les expérimentations qui sont exposées ici sont celles qui réalisées avant l'hiver 1976-1977 auront fait l'objet d'au moins une campagne de mesures en saison de chauffe avant leur presentation au C.C.M.S. en 1977.

A. Sous le contrôle experimental du PLAN CONSTRUCTION :

1. PAVILLONS À CHAUFFAGE SOLAIRE ÉQUIPÉS DE CAPTEURS RUISSELANTS LIEBARD

Cette expérimentation permettra de tester au plan technique et économique trois types de solutions sur un ensemble de 10 pavillons H.L.M. situés à BLAGNAC.

- Chauffage mixte solaire-gaz et production d'eau chaude sanitaire solaire-gaz, avec *capteurs ruisselants* (5 pavillons)
- Chauffage au gaz et production d'eau chaude sanitaire mixte solaire-gaz (3 pavillons)
- Chauffage et production d'eau chaude sanitaire au gaz (2 pavillons de référence).

Sur ces pavillons identiques d'un volume unitaire de 250 m^3 on appréciera ainsi *l'efficacité des capteurs ruisselants LIEBARD*

- pour le préchauffage de l'eau chaude sanitaire
- pour le chauffage principal avec appoint au gaz

L'économie attendue est de 50% pour des surcoûts d'investissement de 25 600 F pour le chauffage des locaux et 1 360 F pour le chauffage de l'eau chaude sanitaire, par rapport à la solution gaz classique de référence.

2. HABITAT COLLECTIF H.L.M. AU ROUSSET (BOUCHES-DU-RHÔNE)

Cette expérimentation porte sur un bloc de 32 logements au sein d'un ensemble de trois blocs de même dimension à quatre niveaux:

Le bloc est dissocié en un demi bloc de référence chauffé entièrement à l'électricité, et en un demi bloc chauffé à l'energie solaire avec appoint électrique direct par convectors.

La captation est réalisée par 120 m^2 de capteurs en terrasse supérieure de l'immeuble et 110 m^2 en surface verticale du pignon sud, ce qui conduit à un ratio de 14 m^2 par logement.

La distribution de l'eau chaude est effectuée par planchers radiants. Une citerne de stockage de 15 m^3 permet d'assurer un déphasage moyen de la demande et des apports de 24 à 48 heures selon la saison.

B. Sous le contrôle expérimental de l'Electricité de France (E.D.F.):

1. VILLAS SOLAIRES "LE PARADIS" à ARAMON (GARD)

Cinq villas ont été choisies pour cette expérimentation parmi 15 villas identiques réservées aux cadres de la centrale thermique de l'E.D.F. à ARAMON. Il s'agit de 2 villas de 5 pièces (325 m^3) et de 3 villas de 7 pieces (376 m^3).

L'ensemble des 15 villas est du type "tout électrique", à forte isolation et à chauffage electrique direct.

Le système expérimenté comprend:

- des insolateurs du type chauffe-eau Roll-Bond en façade verticale Sud (35 - 38 m^2)
- un stockage d'eau chaude en sous sol (4 m^3)
- une distribution d'eau chaude dans les dalles du sol
- le chauffage électrique d'appoint par convecteurs électriques indépendants thermostatés.

Soulignons quelques points essentiels de l'expérimentation:

- A l'exception d'une des maisons qui est restée vide pendant environ un an, cet ensemble de constructions est habité.
- Un dispositif complet de mesure permet de contrôler les températures des fluides caloporteurs à tous les niveaux ainsi que les températures d'ambiances intérieures et extérieures des villas.
- L'économie de consommation doit se siteur entre 55 et 65% de l'énergie utilisée pour le chauffage électrique intégré traditionnel (chauffage des locaux et production d'eau chaude sanitaire). Cet objectif sera directement contrôlable par différence des consommations entre les maisons "solarisees" et les maisons de reference tout electrique.

2. VILLAS SOLAIRES DU HAVRE (SEINE-MARITIME)

Il s'agit de cinq habitations appartenant à un ensemble de villas réalisé par la Société H.L.M. du Foyer Havrais. Leurs caractéristiques sont les suivantes:

- Surface 108 m^2 — Volume 270 m^3.
- Insolateur du type chauffe eau Roll-Bond de 46 m^2, incliné à 61° (latitude + 11°30) et à 45°30.
- Stockage d'eau chaude en sous-sol de 4 m^3
- Distribution par ventilo-convecteurs à eau
- Chauffage électrique d'appoint dans les ventilo-convecteurs.

L'ensemble des réalisations de l'E.D.F. est en service depuis la fin 1975. Fondées sur le principe de l'appoint tout électrique, les expériences comparées d'ARAMON et due HAVRE fourniront des renseignements sur les économies potentielles d'energie électrique de chauffage pour des conditions climatiques très différentes.

C. Sous le contrôle expérimental du COSTIC:

1. LE CHAUFFAGE DU FOYER DE L'ECOLE NATIONALE TECHNIQUE DES MINES D'ALES

Pour une puissance installée en chauffage d'appoint au gaz et de secours de 30 000 Kcah/h l'installation solaire est consituée de:

- 54 m^2 de capteurs orientés au Sud et inclinés à 60° sur l'horizontale.
- un stockage en ballon de 500 litres

La régulation particulièrement étudiée comprend:

- une régulation de la captation
- une régulation de la distribution (fourniture directe par les capteurs, fourniture à partir du stockage, recirculation)
- une régulation pour l'alimentation en eau chaude sanitaire.

Une simulation numérique sur ordinateur avec LOGICIEL HELIOS a permis d'optimiser le rapport surface de captation / coût de l'opération. Il est attendu une économie d'énergie de l'ordre de 50%.

2. CHAUFFAGE DE L'HÔTEL DES IMPOTS DE SALON

Les installations de chauffage solaire avec appoint et secours gaz d'une puissance de 315 000 Kcal/h doivent assurer:

- le chauffage des locaux de bureaux, circulations, sanitaires et archives
- le chauffage d'un logement de fonction
- la production d'eau chaude sanitaire

Les installations solaires comprennent:

- 342 m^2 d'insolateurs en terrasse
- un stockage de 5000 litres en sous sol (0 95°C)
- une protection antigel par recirculation

L'énergie d'appoint est commutée dès que la température le sortie du stockage est inférieure à 60°C.

GREECE: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

A. Deliyannis
Nuclear Research Center "Demokritos"

A special format report will be prepared on the solar heating system designed to heat 12 rooms of the new Administration Building of the Nuclear Research Center "Demokritos." A reflecting horizontal solar collector has been developed and will be incorporated into the above mentioned project. A preliminary format report on the solar heating project and the collectors was prepared and distributed at the Copenhagen meeting.

THE NETHERLANDS: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

C. den Ouden
Institute of Applied Physics (TNO)

The Netherlands will prepare Special Format Reports during the coming year (1977) on the following projects:

1) One of the 4 energy saving dwellings in Oss

   25 m^2 combined collector and storage system made of 30 m thick concrete slabs.

2) Solar heated house in Eindhoven (Professor v. Koppen)

   50 m^2 collector area; 5 m storage tank (water), with a special device to increase stratification.

3) One of the 4 Solar heated houses in Zoetermeer (Bredero Company)

   40 m^2 collector area; 2 m^3 storage tank (water).

4) The 2/3 story laboratory in Enschede

   400 m^2 collector area; 50-100 m^3 storage tank (water).

It is possible that the reports on the projects mentioned under 3 and 4 will be distributed at the beginning of 1978.

SWEDEN: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

Lars Engström
Uhlin & Malm, Architects

The following Special Format Reports will be prepared in 1977:

1) Completion of the report on the Euroc House, Limhamn.
2) Completion of the report on the Ostgotabyggen House, Linkoping.
3) Preliminary report on the STR House, Vetlanda.
4) Details of the Ostgotabyggen central storage project, Linkoping.
5) Preliminary report on the joint Building Technology-Physical Chemistry Institutions (Technical University of Stockholm) project.

TURKEY: PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

Systems to be reported in 1977 special format reports will be selected from among projects referred to in the national programs section.

UNITED STATES:
PROJECTS FOR 1977 SPECIAL FORMAT REPORTS

F. H. Morse
Division of Solar Energy
Energy Research and Development Administration

During the forthcoming year, the United States will prepare and distribute ten Special Format Reports. Three will pertain to large-scale solar heated and cooled commercial buildings in different climatic regions of the United States. Four will deal with the use of solar energy for agricultural and industrial process heat application. The remaining reports will pertain to evaluations performed by universities of existing solar energy systems in residential buildings. These ten projects are briefly described below.

1) Solar Heating and Cooling of a City Community Center

The city of Santa Clara, California generates its own electric power and expects its requirements for electric power to double in the next six years. To reduce the growth of its energy demand, the city is designing, procuring, installing, and operating a solar heating and cooling system for a new community center. This center has an area of 27,000 sq. ft. and is located in an area of California where the average temperature varies from 54.6°F in winter to 67.6°F in summer.

The solar heating and cooling system utilizes 6,976 sq. ft. of selectively coated copper absorber flat plate collectors and includes a water storage capacity of 60,000 gallons. This system is expected to provide 84% of the energy required for heating, 65% of the cooling energy required and all of the domestic hot water. It has two Arkla 25-ton absorption chillers. The building has non-insulated 8" thick concrete block walls. The technical, legal, and financial feasibility of the system will be examined. Cost and performance data will be analyzed to determine whether solar energy can be used to lessen the demand for electric power. The Santa Clara Community Center was visited during the 1975 CCMS Annual Meeting in Palo Alto, California.

2) Retrofit Heating, Cooling and Hot Water System For an Elementary School

The George A. Towns Elementary School in Atlanta, Georgia, was retrofitted with a solar energy system designed to provide 50% of the heating, 60% of the cooling, and 80% of the hot water requirements. This system includes approximately 10,500 sq. ft. of roof-mounted Pittsburgh Plate Glass aluminum rollbond liquid flat-plate collectors augmented by 10,800 sq. ft. of reflector area, three underground 15,000 gallon thermal storage tanks and a 100-ton Arkla absorption chiller.

Besides reducing conventional energy consumption, the solar energy system is providing data on several critical points — the performance of the mass-produced collectors, for instance, and the system's capacity to function under high temperatures (200°F). The Atlanta area averages 3,095 heating degree days per year; the average temperature in winter is 51°F and in summer is 74.5°F.

3) Solar Heating and Cooling of an Office/Laboratory

The performance of a solar heating and cooling system in the Department of Agriculture Building on the campus of the New Mexico State University is being evaluated. The newly constructed building has an area of approximately 25,000 sq. ft. and its solar system is designed to provide 80% of the heating and cooling requirements. The system utilizes 6,190 sq. ft. of Miromit flat-plate collectors, 540 sq. ft. of Northrup concentrating collectors, a 100-ton York absorption chiller and a 25-ton Arkla absorption chiller. It has storage capacity for 30,000 gallons of ethelyne glycol water solution.

An automated data acquisition system has been designed and will be used to verify the performance predictions based on the use of detailed simulation programs for this facility. Analysis includes evaluation of flow sensors installed in the system, performance testing of the prototype multiplexer/analog to digital conversion equipment and pyranometer comparison testing. The building project and its solar system design were funded by the Legislature of the State of New Mexico. The building was occupied on October 15, 1975.

4) Design of Collectors and Instrumentation for Application to Solar Drying Peanuts

This project, located at the Georgia Institute of Technology in Atlanta, will design, fabricate, and furnish plans and units for the field evaluation of several different configurations of improved solar energy collectors for agricultural dryers, specifically oriented toward reducing the fossil fuel energy currently consumed in the peanut, forage, and tobacco drying processes. Instrumentation for applying the collectors to the specific processes will also be developed. The economic and engineering approach will be chosen to make immediate utilization an attractive possibility, and the results of this project will be widely disseminated.

5) Solar Energy Assisted Heat Pump Grain Drying

The objective of this project, conducted by the University of Illinois, is to determine the economic and technical feasibility of using solar energy alone and in combination with a heat pump system for drying corn. The approach will be to explore the use of a heat pump drying system in combination with solar drying in order to maintain drying potential during the night and during other periods of low insolation. The performance of flat building roofs and bare metal plates on grain bin sidewalls as solar collectors for grain drying will also be evaluated.

6) Use of Solar Energy for Poultry House Heating and Manure Drying

The objective of this project is to develop methods for modification of conventional roof surfaces for collection of solar energy for caged-layer poultry houses. Mississippi State University is performing this research. The roof of a typical caged house will be converted into solar collectors by painting it black, installing plastic and glass covers, and providing air passages on the lower side. The collected heat will be used to maintain environmental temperature for the caged layers and for drying manure produced by caged layers. The efficiency of this system will be evaluated.

7) Heating Greenhouses With Solar Energy

Rutgers University in New Brunswick, New Jersey, will develop and evaluate practical systems for heating greenhouses with warm water obtained from low-cost solar collectors, and develop techniques for reducing heat losses from greenhouses.

The University will determine specific mechanisms of heat losses from greenhouses utilizing an instrumented outdoor greenhouse and an environmental chamber. They will develop and test methods of reducing heat losses with multiple layers of plastic, reflective insulation, movable insulation shields of various materials, or other means. Low cost solar heat collectors from layers of clear and black plastic films using water and air as fluids will be investigated. Methods of exchanging heat between warmed water and the greenhouse through warm soil beds, circulating water in plastic envelopes on the floor, and warm water circulating between multiple layers of the roof and walls will also be explored.

8) Evaluation of High Performance Collectors in a Residential Heating and Cooling System

As part of a joint project between the U.S. and the Federal Republic of Germany, the Solar Energy Applications Laboratory of Colorado State University will install arrays of Corning evacuated tubular collectors and Philips Mark IV evacuated tubular collectors on a test bed adjacent to the University's Solar House I. The Corning collectors will be used to operate the house's solar heating and cooling sytem during the first year, and the Philips collectors will be utilized during the second year. Data will be collected over an entire heating and cooling season and analysis will be performed on these data. This will provide an evaluation and comparison of the performance of the tubular collectors and the present conventional collectors, as part of a residential heating and cooling system that is otherwise identical in every way.

9) Evaluation of a Residential Solar Air Heating System

The solar system to be utilized consists of a solar air heating collector, pebble-bed storage (storage of both heat and "cold"), and a day/night exchange cooling system, installed in Solar House III at Colorado State University. This system is commercially available. The objective of this project is to compare the performance of an air system and a water heating system, the latter installed in an adjacent building with virtually identical thermal characteristics. The program is divided into the following task areas: (1) system performance analysis, (2) comparison of system performance with CSU Solar Houses I and II, and (3) providing opportunities for transfer of information to the public.

10) Analysis of a Retrofitted Solar Heated Row Home

The objective of this project is to produce practical (technical and economical) guidelines for the retrofit and operating of existing row houses to utilize solar energy for comfort heating and domestic hot water. Means of introducing solar heating systems in the urban environment in general will also be addressed in this study. The study will include the questions of building codes, zoning laws, insurance, legal aspects and social acceptance. The retrofit system was funded by the Department of Housing and Urban Development as part of the residential demonstration program, and the University of Pennsylvania will conduct the evaluations. As a by-product, hourly weather and insolation data for Philadelphia for a period of two years will be obtained.

Three collector flow rates (10, 14, 20 lbs/hr ft^2) and three thermal water storage capacities (600, 800 and 1000 gallons) will be studied. There will also be variations in control logic parameters in terms of interstage difference and differential on the differential thermostat, temperature setting of the freeze protection system, and solar heat supply system shutdown level.

VI. GENERAL DISCUSSION

MEMORANDUM OF UNDERSTANDING

The framework for the format of the information exchange within the CCMS Solar Energy Pilot Study is provided in the "Memorandum of Understanding Concerning Cooperative Information Exchange Relating to the Development of Solar Heating and Cooling Systems in Buildings". This document was drafted by a committee of experts at the 1974 CCMS meeting in Odeillo, France. The United States, in its role as pilot country and depositary of the MOU, circulated the document, with minor revisions, in 1975 to the NATO countries and to other nations participating in the Pilot Study for signature. On July 1, 1975, the Memorandum of Understanding entered into force for those signatories who had signed on or before that date. Its provisions are applicable to all other parties on the date of signature.

At the time of the 1975 CCMS solar meeting in Palo Alto, California, the appropriate agencies of Australia, Canada, the FRG, Greece, Israel, Italy and the United States had signed the MOU. In the intervening year, agencies of five additional countries – Belgium, Denmark, France, Jamaica, and the United Kingdom – signed the Memorandum of Understanding. During the 1976 CCMS meeting in Copenhagen, representatives from the Netherlands, Spain and Turkey indicated their national solar agencies would sign the MOU in the near future, and Iran also expressed its interest in participation. (Since the Copenhagen meeting, New Zealand has also indicated its desire to become a party to the MOU).

During the meeting in Copenhagen the participating countries discussed facilitating the exchange of information carried out under the Memorandum of Understanding. Each country agreed to take steps appropriate to its national circumstances to insure that researchers in the solar field are made aware of the reports available through this exchange mechanism.

The full text of the Memorandum of Understanding is found in *Appendix F*

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*Report prepared by Ms. Edwina Campbell, U.S.A.

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CCMS SYSTEM REPORTING FORMAT

BACKGROUND

At the 1974 CCMS Solar Energy Pilot Study Meeting in Odeillo, a committee was formed to develop a System Reporting Format. The following year, after review and discussion, a Recommended Reporting Format was adopted by the delegates at the Palo Alto Meeting.

The System Reporting Format, described in detail in Appendix G, is divided into two portions, one pertains to system performance and the other deals with sub-system performance, e.g. the performance of the collectors within the system. Three general areas are covered in describing the system performance. The first is a general description of the project and environment, including a brief description of the purpose and strategy of the project, a general description of the climate, location, insolation, temperature and wind features of the test site, and a description of the system being tested. The next section describes the thermal performance of the system, with emphasis on monthly values of the solar and supplementary energy quantities. The last section of the system portion covers the economic aspects, including various costs and economic factors, as well as maintenance and user reaction information. The portion dealing with sub-system performance describes the required descriptive information on the sub-system, as well as the type of thermal performance characteristics that are requested.

A major development during the past year has been the adoption of the Reporting Format by the Solar Energy Working Group of the International Energy Agency. Also, several countries are adopting the Reporting Format for using in connection with their national solar energy programs. These adoptions give additional weight and authority to the Reporting Format. At the same time, these adoptions will inevitably be followed by alterations in format content to meet the specific needs of the agency or country. Thus it will be desirable for this project to refer to the "CCMS System Reporting Format" in order to distinguish it from other reporting formats.

DISCUSSION

The System Reporting Format Committee met during the CCMS Copenhagen meeting to discuss the status of the System Reporting Format. The countries participating in this meeting were: Australia, Denmark, FRG, France, Greece, The Netherlands, Sweden, and the United States. A current list of the representatives to the System Reporting Format Committee will be found in *Appendix F*. It should be noted that membership is not exclusive, and that any country having a vital interest in the application of the format may signify to the committee chairman its wish to place a representative on the committee.

The results of the discussion of the System Reporting Format Committee were presented to the General Discussion Session for further consideration by all countries. The committee report noted that, to date, authors of Special Format Reports have found the CCMS System Reporting Format to be very comprehensive in its requirements for a description of the performance of their solar heating (or heating and cooling) system. It was also noted that some additional detailed instructions should be added to the System Reporting Format to clarify the requirements and to elicit a more uniform response to items called for. Further, it was suggested that some items be deleted and others added. In particular, it was felt that the reporting of the system thermal performance on a daily basis was too lengthy and cumbersome and should be deleted. It was suggested that daily performance be replaced by hourly results for sample days, preferrably in a graphical form. As an alternative to the latter proposal, it was suggested that the report indicate how a reader could obtain hourly results for use in computer simulations.

Because of the intimate relation between building envelope performance and solar space conditioning system performance, it was proposed that additional information on the building envelope should be required. In the case of passive systems, this information is essential. It was pointed out that the group working on the International Energy Agency format has basically adopted that CCMS System Reporting Format with the addition of a quantitative description of the building and the addition of building thermal performance information.

The Format Committee also found that the experience of readers of Format Reports on particular projects indicated the desirability of a format summary being appended to each Format Report. It was agreed in the General Discussion Session that this summary should (a) be designed by the Format Committee and (b) not in any way replace the full Format Report on the project (i.e., it should be attached to the full Format Report just as an abstract accompanies an article in a journal publication). The committee chairman was asked to prepare a draft of a recommended summary outline and submit it to the committee members. The final version incorporating committee members suggestions will be circulated to the contact persons.

It was noted in the general discussion among the delegates that inasmuch as the System Reporting Format is in its trial period, it should continue to be utilized in its present form. It was concluded that a thorough review would take place in the coming year and revisions and modifications will be considered at the end of that period.

ZERO ENERGY HOUSE GROUP*

BACKGROUND

In the context of this pilot study, a Zero Energy House is one in which solar energy is used to meet the significantly reduced energy needs of buildings incorporating various thermal energy conservation subsystems. Measures to reduce energy consumption focus on the reduction of heat losses (through windows, walls, floors, and ceilings), recovery of waste heat (in water and exhaust air), usage of alternative energy sources (solar energy, both directly and through the earth), and building optimized integrated energy systems. The objective of these projects is to study the performance of buildings requiring essentially zero or minimal energy from conventional fuels.

As a result of the interest of many participating countries, particularly those with northern European-type climates, in such minimum energy dwellings, a Zero Energy House Group was formed within the Solar Energy Pilot Study in 1974. Two meetings of the group have been held thus far to exchange information on projects underway involving energy-conserving dwellings utilizing solar energy.

SUMMARY OF ZERO ENERGY HOUSE GROUP MEETINGS

The Zero Energy House Group, chaired by Professor Vagn Korsgaard, of Denmark, held its first meeting during January 30-31, 1975, when fifteen representatives from six countries met at the Technical University of Denmark in Copenhagen. The six participating countries were: Denmark, The Federal Republic of Germany, The Netherlands, Sweden, the United Kingdom, and the United States.

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*Report prepared by Torben V. Esbensen, Denmark.

Each of the participating countries gave a detailed presentation of the current projects related to energy conservation and solar heating systems in buildings. A meeting report on the Copenhagen Zero Energy House Experts Meeting is presented in the "Report to the CCMS Spring 1975 Plenary".

The second Zero Energy House Experts Meeting was held at the Philips Research Laboratory in Aachen, Federal Republic of Germany, during May 26-28, 1975. Thirty-six representatives from eight countries participated in this meeting: Canada, Denmark, Federal Republic of Germany, The Netherlands, Sweden, the United Kingdom, and the United States.

At the meeting there was a detailed presentation and discussion about solar collectors and long-term heat storage systems. A meeting report on the Aachen Zero Energy House Experts Meeting was prepared by the Philips Research Laboratory and appears in the "Report to the CCMS Fall 1975 Plenary".

The third Zero Energy House Experts Meeting will probably be held in Sweden during the spring of 1977. At this time all the above-mentioned solar heated houses have been in operation for more than one year, and therefore it will be possible for the participants to exchange experience in details.

MEETINGS RELATING TO THE ZERO ENERGY HOUSE GROUP

On April 22, 1976 the U.K.-Section of the International Solar Energy Society held a meeting in London on "European Solar Houses". At this meeting reports on the following projects were presented:

1) The Philips Solar House in Aachen, The Federal Republic of Germany.
2) The Euroc Solar House in Limhamn, Sweden.
3) The Zero Energy House in Lyngby, Copenhagen, Denmark.
4) The BRE Low Energy Houses in Watford, the United Kingdom.
5) The Milton Keynes Solar House in the United Kingdom.

On May 17th-18th, 1976 the Swedish Building Research Council held a meeting in Stockholm on "Scandinavian Solar Houses". At this meeting, reports on several projects were presented according to a revised CCMS Reporting Format. The following projects were presented:

1) The Euroc Solar House in Limhamn, Sweden
2) The Östgötabyggen Solar House in Linkoping, Sweden.
3) The STR Low Energy House in Vetlanda, Sweden (in design phase)
4) The Zero Energy House in Lyngby, Copenhagen, Denmark.

PROJECTS

The status of zero or minimum energy house projects currently underway in participating countries is as follows:

DENMARK

An experimental house (120 sq m floor area) has been constructed at the Technical University of Denmark. Operation of this house commenced in April 1975. The solar heating system of the house is sized to cover the heat load for the house, 2300 kWh, and the hot water supply of 2300 kWh, during a whole year with weather data corresponding to a "Reference Year". The Reference Year was constructed by scanning ten years' data of seven major and five minor measurements, such as dry bulb temperature, moisture etc. The system consists of a vertical flat-plate solar collector of 42 sq m, a water storage tank of 30 m^3, and a combined ventilation and warm air heating system. Heat recovery is applied on the ventilating air and water.

FEDERAL REPUBLIC OF GERMANY

A solar heated experimental house has been built at the Philips Research Laboratory in Aachen and began operation in June 1975. High-insulated construction and heat recovery equipment reduce the heat load for the house to 8300 kWh a year. Specifically designed 20 sq m flat-plate solar collectors (inclined at 45 degrees) combined with 40 cu m water storage tanks are able to cover the total heat requirement for the 120 sq m experimental house.

THE NETHERLANDS

A test project consisting of four solar heated houses in a group of twelve homes in a new low-cost housing development in Oss has been started. The dwellings concerned are so-called "low-cost dwellings". Four homes have good insulation, forced air-heated ventilation and solar collectors. Four other homes have normal insulation, three with water heating, and one with air heating. The final four homes have an experimental air heating system with different types of heat recovery. The complete project will determine what fuel savings can be attained by various measures.

SWEDEN

Two solar heated experimental houses have been built in Sweden, beginning operation during the summer of 1975.

The "Termoroc-House" built by Euroc in Limhamn has many energy conservation arrangements for the purpose of reducing the heat load for space heating and hot water supply. The solar heating system of the house is dimensioned to cover 50 per cent of the heat load, 15000 kWh. The system consists of a 50 m^2 flat-plate solar collector (inclined at 70 degrees) and a water storage tank of about 3 m^3.

The solar house in Linkoping built by "AB Östgötabyggen" has a solar heating system designed to cover 40 – 60 per cent of the total heat load, 25000 kWh. The system consists of 50 m^2 flat-plate solar collector (inclined at 45 degrees) and a water storage tank of 8 m^3.

UNITED KINGDOM

Three low-energy houses are under construction at the Building Research Establishment in Watford:

1) Air heating by heat pump alone.
2) Air heating and heat recovery.
3) Flat-plate solar collector and a storage system using 3 tanks.

NEW GROUPS

BACKGROUND

At the 1975 Palo Alto meeting, it became apparent that there were many aspects of solar heating and cooling of buildings common to the programs and projects of certain groups of countries, particularly in similar climatic regions. Noting the effective activities of the Zero Energy House Group (directed at solar heating and cooling activities in northern European climates), it was decided to explore the interest of participating countries in the formation of additional groups in which exchange of technical information would focus on solar energy applications in other climatic regions. A letter was circulated by the United States to assess preliminary interest in the formation of new groups on Mediterranean climate applications of solar energy and tropical applications of solar energy. Since the general response was favorable, meetings and discussions were held at the 1976 Copenhagen meeting on the formation of these new groups. The results of these discussions are detailed below.

MEDITERRANEAN-CLIMATE APPLICATIONS GROUP*

The representatives of countries interested in the possible formation of a group on Mediterranean Climate Applications met during the 1976 Copenhagen meeting. Participating in the meeting were: Turkey, Greece, Saudi Arabia, Israel, Spain, USA, FRG and France. These participants, after the discussions described herein, agreed to form a Group on Mediterranean Climate Applications. Since then, Australia and Iran have indicated their interest and readiness to participate. (Italy, which was not represented at Copenhagen, is also expected to participate).

Those present were assured by representatives of the US and NATO that there was no limitation on countries which could participate and that contact would be made with all countries likely to have an interest in the group before the end of 1976.

The participants attempted, as a beginning, to define the characteristics of a "Mediterranean Climate":

(a) relatively cold winters and humid and dry summers (or relatively dry).
(b) generally clear summer nights
(c) cooling desirable in summer
(d) short period of heating required

This last point (d) was considered important since it limits the economic competitiveness of heating systems (other than passive heating methods) which do not have alternative uses when heating is not required. On the other hand, cooling during periods of heat would appear desirable, preferably by simple methods.

Based on the above, and attempting to outline more general applications, the participants tried to define specific applications of solar energy in this type of climate, which would be the object of close cooperation within this new group:

(a) passive heating and cooling systems (which should be the focus of a special effort)
(b) studies on the traditional living environment and especially on material and sociological aspects of dwellings

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*Report prepared by J. F. Robert, France

(c) cooling methods using evaporation
(d) cooling methods using nocturnal radiation
(e) solar ponds which are particularly appropriate to this type of climate
(f) studies on water saving
(g) systems of distillation, whether or not associated with the production of mineral salts
(h) specific aspects of meteorology, particularly those bearing on nocturnal radiation.

This list may be either too ambitious or may be incomplete. For this reason France, which agreed to serve as chairman of the group, proposed to contact before the end of 1976, all of the countries which might be interested, in order to clarify these points and eventually to increase the number of participants. France also hopes to organize before the middle of 1977 a meeting of all participants at which projects and developments in these areas of common interest will be discussed.

TROPICAL APPLICATIONS GROUP

There was not sufficient interest expressed in the formation of a group on Tropical Applications of Solar Energy by the countries represented at the Copenhagen Meeting. It is possible that the needs of the majority of countries currently participating in the pilot study are served by the Zero Energy House Group and the newly formed Mediterranean Climate Applications Group. After some discussion, it was decided not to actively pursue formation of such a group at this time.

INFORMATION DISSEMINATION

REPORTS EXCHANGED

One of the key elements of the CCMS Solar Energy Pilot Study, as stated in the Memorandum of Understanding, is the exchange of both general reports on solar heating and cooling of buildings and special format reports which describe system and subsystem performance of projects according to the CCMS reporting format. The goal of this exchange of reports is to encourage and facilitate the cost-effective and practical application of solar energy by informing participating countries of research, projects, and performance results in the programs of other countries.

Since the 1975 Palo Alto Meeting, forty general reports and special format reports have been distributed by nine participating countries as part of the CCMS Solar Energy Pilot Study information exchange. These figures represent a significant increase in the number of countries distributing reports and the total number of reports involved. As programs and projects progress, a further increase in the level of participation is expected.

A complete list of general and special format reports, distributed since September 1975, can be found in Appendix I.

CENTRAL INFORMATION HANDLING PERSON

The effectiveness of the information exchange is dependent, to a large extent, on the timely and widespread distribution of exchanged reports. As solar research programs expand and the number of researchers increases, it becomes difficult, in many cases, for contact persons to effect comprehensive circulation of reports, or even notification of their availability, to appropriate researchers. At the Palo Alto meeting it was therefore decided that each contact person would be requested to identify a central technical information organization (or a person within such an agency) to receive a copy of CCMS-distributed reports and assist in their dissemination. The desirability of designating an information person or organization was reaffirmed at the Copenhagen meeting. A list of central information contacts is found in Appendix E. For those countries which have chosen an information handling contact, one copy of all distributed reports should be sent to the contact person and the second copy to the information handling contact. In the case of those countries which have not yet designated an information contact, the contact person should continue to receive both copies of exchanged reports.

U.S. INFORMATION DISSEMINATION SYSTEM

Each participating country is responsible for setting up its own internal dissemination system for reports received from other CCMS countries. The United States system is described here briefly as one example of the manner in which general reports and special format reports are handled.

Reports Received By the U.S.

When the United States receives a general or special format report from a CCMS country, one copy goes to the ERDA Technical Information Center (TIC) in Oak Ridge, Tennessee. In the past the U.S. contact person was responsible for sending foreign reports to TIC. However, under the new system, one copy of each report will now be sent directly to the U.S. information handling person at TIC by the participating country distributing the report. (The second copy should be sent to the U.S. contact person.) The document will be listed in the abstract journal *"Solar Energy Update"* and possibly other ERDA energy abstract journals. In some cases ERDA will determine that translation of foreign-language documents into English is warranted. If ERDA so elects, these documents may be reproduced in printed copy and distributed without charge to those on the ERDA Solar Heating and Cooling mailing list. Microfiche copies are sold to libraries, research groups and firms. The documents may also be purchased by the private sector through the government technical sales agency, The National Technical Information Service (NTIS). NTIS will sell U.S. reports to any requester, but foreign reports are available only to U.S. residents. Those living outside the U.S. are expected to deal with the originating country to obtain a non-U.S. report.

In order to inform appropriate researchers in as timely a manner as possible of foreign reports dealing with their area of interest, the U.S. has instituted a new plan: A copy of the title page plus abstract and/or table of contents will be sent to ERDA contractors working in similar areas of solar applications, along with information on how copies may be ordered from NTIS.

Reports Originating In The U.S.

United States special format reports and general reports are sent to the central information handling person and/or contact person of participating countries. Special format reports are sent to TIC and handled in the same manner as non-U.S. special format reports. Almost without exception, all general reports distributed by the U.S. will already be contained in the TIC data base and are available for purchase from NTIS. Both U.S. residents and foreign individuals wishing to purchase additional copies should address their requests to the National Technical Information Service.

To order the *"Solar Energy Update"* abstract journal ($40/year for foreign subscriptions – 12 issues) or to order documents or microfiche from NTIS, contact:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22151
USA

NEXT PILOT STUDY MEETING

The delegate from the Federal Republic of Germany extended an invitation to host the next CCMS Solar Energy Pilot Study Meeting in early spring 1978. This invitation was accepted by the pilot and co-pilot countries. The meeting will include a conference devoted to papers on the performance of solar heating and cooling system projects, prepared in accordance with the CCMS System Reporting Format. The papers will be presented by designated representatives of the countries participating in the pilot study. This conference will be widely publicized and will be open to attendance by solar energy researchers. The purpose of this CCMS conference is to provide another means for the R & D community to learn about the performance of the many systems which have been discussed at the annual meetings of this pilot study. The portion of the CCMS Solar Energy Pilot Study annual meeting devoted to all other pilot study matters will be conducted in the same manner as in the past, with participation limited to delegations from invited countries. It is tentatively planned to allocate 2 - 3 days to the CCMS Solar Energy Pilot Study business meeting and 2 days to the open conference.

VII. APPENDIX

APPENDIX A

COUNTRIES INVITED* TO THE CCMS SOLAR ENERGY PILOT STUDY MEETING

COPENHAGEN – SEPTEMBER 13-15, 1976

NATO COUNTRIES

- ** Belgium
- ** Canada
- ** Denmark
- ** Federal Republic of Germany
- ** France
- ** Greece
- Iceland
- Italy
- ** Luxembourg
- ** The Netherlands
- Norway
- Portugal
- ** Turkey
- United Kingdom
- ** United States

NON-NATO COUNTRIES

- Argentina
- ** Australia
- The Bahamas
- Barbados
- Bolivia
- Brazil
- Chile
- Columbia
- Costa Rica
- Dominican Republic
- Ecuador
- El Savador
- Guatemala
- Guyana
- ** Haiti
- Honduras
- India
- ** Iran
- ** Israel
- Jamaica
- Japan
- ** Mexico
- ** Monaco
- New Zealand
- Nicaragua
- Nigeria
- Pakistan
- Panama
- Paraguay
- Peru
- The Philippines
- ** Saudi Arabia
- ** Spain
- Sudan
- ** Sweden
- Trinidad
- Uruguay
- Venezuela

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* Invitations sent by the United States (pilot country) on behalf of France and Denmark (co-pilot countries) and the United States.

** Accepted invitation and sent a representative to the Copenhagen meeting.

APPENDIX B

LIST OF PARTICIPANTS
1976 COPENHAGEN CCMS MEETING

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* Indicates contact person or acting contact person

APPENDIX C

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APPENDIX E

CCMS SOLAR ENERGY PILOT STUDY
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FEDERAL REPUBLIC OF GERMANY
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British Library
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Wetherby, West Yorkshire LS23 7BQ
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APPENDIX F

MEMORANDUM OF UNDERSTANDING CONCERNING COOPERATIVE INFORMATION EXCHANGE RELATING TO THE DEVELOPMENT OF SOLAR HEATING AND COOLING SYSTEMS IN BUILDINGS

The agencies which have signed the Memorandum of Understanding,

Recognizing that there are within the territories of the governments of the parties to the Memorandum of Understanding, governmental and industrially-sponsored programs which collectively form a broad-based attack on the challenging energy problems facing our societies, and

Believing that international cooperation in the field of solar energy for heating and cooling processes in buildings will prove fruitful for all concerned, and desiring to undertake a comprehensive exchange of knowledge gained about the design, the technical characteristics, and the performance of solar energy systems and subsystems developed in the course of conducting and monitoring projects related to solar heating and cooling in buildings,

Agree as follows:

1. The aim of this Memorandum of Understanding is to encourage the cost-effective and practical application of solar energy to heating and cooling in residential, commercial, industrial, agricultural and public buildings. This aim shall be accomplished through the exchange of information related to research programs and experiments and by developing an agreed format for reporting performance characteristics of solar heating and cooling systems in such applications. Information respecting the performance of the major subsystems shall be included in the exchange, together with information respecting whole systems experiments relating to the effectiveness of solar energy in heating and cooling processes in buildings. Information exchange respecting both subsystems and whole systems shall, to the maximum feasible extent, include data relating the experiment to the thermal requirements and climatological and societal conditions involved.

2. Each signatory to the Memorandum of Understanding shall appoint a representative through whom the information specified above shall be exchanged. Each signatory shall send to all other signatories special reports – prepared in an agreed format-on projects under the sponsorship or coordination, or with the participation of the signatory, at significant stages of work on solar heating and cooling processes in buildings, and of relevant and publically available reports concerned in whole or in part with the subject matter of the Memorandum of Understanding. Copies of (a) the special reports in the agreed format, (b) of the full reports upon reasonable request, and (c) of additional material of general interest shall be sent expeditiously to the representative designated by each signatory. The signatories agree also to the maximum feasible extent to dispatch to the other signatories relevant information published by other governmental institutions, universities, private corporations and groups, and technical societies in their country.

3. Additionally, the parties will participate in meetings, which are expected to be held at least annually, for the review of research and development programs and for discussions and exchange of information and ideas for further research.

4. Participation in the agreements established by this Memorandum of Understanding and annexes is subject to the laws of the respective countries. This includes laws respecting the protection of proprietary data and rights in intellectual property, including patents and copyright. All signatories agree to respect any such rights as may be established in accordance with the laws of other signatories as may relate to this Memorandum of Understanding. Participation is further subject to the availability of appropriations to each signatory, as such availability may be determined in accordance with the legal processes of the government of the individual country.

5. The signatories shall exercise their best efforts hereunder to ensure that all data in the subject area of this Memorandum of Understanding can be exchanged and will not be subject to claims for confidential treatment of any kind. Where, however, a private contractor or grantee maintains such claims despite the efforts to avoid such claims required herein, the signatories shall encourage such contractors or grantees to exchange data subject to such claims with other signatories to this Memorandum of Understanding, through special agreements or otherwise.

6. It is contemplated that a number of detailed procedures will be developed for cooperative efforts between agencies and will be incorporated as annexes to the original of this Memorandum of Understanding. When two or more signatories to this Memorandum of Understanding develop more specific relationships on subprograms or projects within the field of this Memorandum of Understanding, details of any agreement or arrangement between them may be annexed to the original of this Memorandum of Understanding.

7. Any signatory may terminate its participation under this Memorandum of Understanding by written notification to all other signatories. Such termination shall be effective 60 days from the date on the notification.

8. The original of this Memorandum of Understanding shall be deposited with the Department of State of the United States of America, which shall transmit two copies of the Memorandum of Understanding to each agency which notifies its intention to become a party hereto. Both copies shall be signed and dated on behalf of the agency and one copy shall be returned to the Department of State, which shall inform all agencies of signatures.

9. This Memorandum of Understanding shall enter into force on July 1, 1975, with respect to those signatories which have signed the Memorandum of Understanding on or before that date. With respect to those which sign subsequently, it shall enter into force on the date of signature.

APPENDIX G

RECOMMENDED
CCMS SOLAR ENERGY PILOT STUDY
SYSTEM REPORTING FORMAT FOR
HEATING AND COOLING SYSTEMS IN BUILDINGS

August 1975

The objective of this system reporting format is to ensure that sufficient information is provided to enable the reader to make his own assessment of the performance of a solar heating and/or cooling system and to relate that performance, which was carried out in one particular climate and economic environment, to a different climate and economic environment.

All details of the format are to be followed as completely as possible. In addition, information on all related back-up reports is requested, including specific instructions on how they may be obtained.

FORMAT FOR REPORTING SYSTEM PERFORMANCE

I. General Description of System Project and Environment

A. Objective of Project

- Brief description of objective and strategy of project, including duration and major milestones.

B. Description of the Environment

1. *Climate*

- Brief description of type of climate, according to the Trewartha* worldwide classification system.
- Annual rain and snow fall (mm per year).
- Description of typical sky conditions relative to "clear sky"; either average daily sunshine hours, number of sunshine hours per year, the percentage of maximum possible sunshine hours or annual average cloud cover fraction may be used.

2. *Location*

- Latitude, longitude, and altitude (in m) of system.
- Description of the configuration of the location and distance from solar or wind obstructions or significant geographic features (sea, mountains, etc., in km).
- Comment on air quality, i.e. dust precipitation.

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*G.T. Trewartha, *An Introduction to Climate* (McGraw Hill: New York, 1968).

3. *Solar Radiation*

- Mean monthly global (total) and, if relevant, diffuse insolation on a surface whose orientation is described. The number of years over which this mean is defined should be specified, as well as the time intervals of the data.
- Description of the measurement equipment.

4. *Ambient Temperatures*

- Mean monthly dry and wet bulb temperatures (relative humidity may be used in place of wet bulb temperature).
- Number and basis of degree-days of location.
- Description of the measurement equipment.

5. *Wind*

- Average monthly wind speed and prevailing direction (0-360° from North towards East).
- Description of measuring equipment.

C. **Description of System**

1. *Qualitative Description*

- Description of the entire system, as well as the solar system, by narrative, photographs, or drawings.

2. *Quantitative Description*

- Description of the system performance characteristics, including schematic drawings.
- Orientation* and inclination+ of collectors.
- Control system description, performance characteristics, and location within the system. The operating modes should be described.
- Measurement system description, performance characteristics (such as precision and repeatability), and location within the system.

II. System Thermal Performance – The information in sections A, B, C and D is essential and therefore should be as complete as possible.

A. **Daily, Monthly and Annual Values** of the Mean Daily** (Tabular or Graphical Form)

- Total energy required (thermal load, heating or cooling, on system).
- Supplemental energy required (amount, kind, and purpose).
- Solar energy incident on collectors.++

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* Angle between the projection of the sun's rays, at solar noon, on the horizontal plane and the projection of the normal to the collector on the horizontal plane.

+ Angle between horizontal and normal to collector.

** The monthly value of the mean daily quantities is the most important of the three. Daily values may be provided as optional information.

++ It is suggested that this be based on (at least) hourly values of the global (and/or direct, if appropriate) insolation measured in the plane of the collectors. If the global insolation is only measured on a horizontal surface, it should be so provided and the method used to determine the amount incident on the plane of the collectors should be described.

- Solar energy collected.
- Solar energy used.

The criteria for the use of supplemental energy must be described.

B. **Record of the Quality of Thermal Performance of the System** (e.g. departure from the design temperature over reporting period)

C. **Solar Contribution to Energy Requirements** – daily, monthly and annual values* of percent solar contribution to the energy requirements.

D. **Monthly and Annual Energy or Fuel Savings** – based on primary fuel (state type).

E. **Energy and Mass Balances**

This information is of secondary importance in that it is this information that is used to determine quantities reported in IIA. If possible, it is suggested (optional) that a typical day be used to show:

- Significant energy flow rates – additions and losses.
- Significant mass flow rates – additions and losses.
- Temperature and pressure at critical locations.
- Temperature drop and pressure drop across major components.

III. System Economic Analysis

The following costs and factors should relate to the solar portion of the project but could also be specified for the entire project.

A. **Total Cost of the Solar Portion of the System** – with a specific definition made of the interface between the solar and non-solar portions of the system. If possible, separate design costs from component and installation costs.

B. **Labor Costs** – in man-hours and in local currency, for the installation of the system.

C. **Materials Costs** – in weight or volume as appropriate and in local currency.

D. **Operational Costs** – including supplemental energy costs, in local currency.

Since operational costs depend on the assumed system lifetime, it is suggested that the assumed system lifetime be stated along with the depreciation rate.

E. **Local Economic Factors** – such as inflation, interest rates and amortization periods.

F. **Expected Selling Price or Costs** – assuming that the system or solar components are mass procuced.

G. **Maintenance Frequency and Costs** – in hours and material.

H. **User Reactions and Comments**

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*The monthly value of the mean daily quantities is the most important of the three. Daily values may be provided as optional information.

FORMAT FOR REPORTING SUB-SYSTEM PERFORMANCE

A. Solar Collectors

1. *Description of Physical Configuration*

   - Description of solar collectors by narrative, photographs, and drawings, including collector materials, design, dimension, and construction.

2. *Thermal Performance Characteristics*

   - Collector efficiency curves (efficiency as a function of average fluid temperature or inlet coolant temperature, ambient air temperature, solar radiation normal to the collector, and wind speed) or equivalent collector performance indication (such as heat production) for several days that typify the full range of operation of the system.
   - Pressure drop through collectors.
   - Optical efficiency vs. incident angle, daily, monthly, and annual optical efficiency.*
   - Thermal loss coefficient as a function of the difference between the ambient and the mean plate temperature, for known wind speeds.*

3. *Lifetime Performance Characteristics*

   - Corrosion
   - Leakage
   - Hot spots
   - Breakage
   - Stability of collector working fluid

B. Heat Transfer Sub-system

1. *Description of Physical Configuration*

   - Description of heat transfer sub-system by narrative, photographs, and drawings. Specify construction materials and working fluids.

2. *Thermal Performance Characteristics**

   - Inlet and outlet temperatures on both sides of exchanger.
   - Inlet and outlet pressures on both sides of exchanger.
   - Mass flow rates on both sides of exchanger.
   - Pumping power.

C. Thermal Energy Storage sub-systems

1. *Description of Physical Configuration*

   - Description of thermal energy storage sub-system by narrative, photographs, and drawings.
   - Specify construction materials and working fluids, location within system, insulation details (material and construction), mass and volume of storage sub-system, storage duration and/or energy stored at same temperature.

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*Optional Information to be included if known.

2. *Thermal Performance Characteristics**

- Mean temperature, hourly and daily, of the immediate surroundings.
- Thermal loss or gain, hourly and daily.
- Storage capacity.
- Inlet and outlet temperatures and pressures.
- Flow rates and pumping power.
- If phase change materials are used, specify compound and thermal characteristics.

D. Air-Conditioning Sub-system

1. *Description of Physical Configuration*

- Description of air-conditioning unit by narrative, photographs and drawings.
- Type of sub-system – heat pump, absorption, passive, etc.
- Heat rejection method.

2. *Thermal Performance Characteristics*

- Capacity at design inlet (to air-conditioning unit) temperature.**
- Capacity$^+$ and coefficient of performance COP curves (inlet temperature as variable).**
- Sensitivity of the capacity and COP to variations in inlet temperature, evaporation temperature, wet and dry bulb temperature.

The International System (S.I.) will be used exclusively^{++} with the following recommendations:

Pressure – given in Kpa.
Temperature – ^{o}C
Energy – MJ and/or Kwh
Solar Flow Rate – Kw, w
Solar Radiation – the intensity will be given in W/m^2, the hourly, daily, monthly or annual totals will be given in MJ/m^2 day averaged over a day, month, or year.
Wind Speed – m/sec
Mass Flow Rate – l/sec or kg/sec

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* This information is of secondary importance in that it is this information that is used to determine the quantities reported in II A. If possible, it is suggested (optional) that a typical day be used to show:
  - Significant energy flow rates – additions and losses.
  - Significant mass flow rates – additions and losses.
  - Temperature and pressure at critical locations.
  - Temperature drop and pressure drop across major components.

** Condenser, absorber and evaporator temperatures should be stated.

+ Including the ratio of sensible to latent heat removal.

++ According to the resolutions of the Converence Génerale des Poids et Mesures, 1960.

APPENDIX H

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APPENDIX I

REPORTS EXCHANGED SINCE SEPTEMBER 1975

GENERAL REPORTS

CANADA	*Technical and Economic Feasibility of Solar Energy Heating in Canada.* K. G. T. Hollands, J. F. Orgill, Waterloo Research Institute, University of Waterloo, Waterloo, Ontario, Yearly Report: Project 4107, April 1976.
	User's Manual for WATSUN – A Solar Heating Simulation and Economic Evaluation Program, J. F. Orgill, K. G. T. Hollands, Waterloo Research Institute, University of Waterloo, Waterloo, Ontario, April 1976.
DENMARK	*Solenergi-dagen, Juni 1976,* Laboratory for Thermal Energy, Technical University of Denmark, June 1976.
FEDERAL REPUBLIC OF GERMANY	*Energy Research and Development Program of the Federal Republic of Germany,* Annual Report 1975, Energy Research Project Management of the KFA Jülich.
	Forschung Aktuell: Sonnenenergie, Hans Matthöfer, editor, Umschau Verlag, Frankfurt am Main, 1976.
FRANCE	*Les capteurs solaires à eau, mesure et extrapolation.* B. Devin, C.E.A. – Service d'Etudes Energêtiques.
	Station autonome de saisie et de concentration de données héliométriques. J. Colomes, M. Gorgeou, C.E.A. – Service d'Etudes Energêtiques.
	Méthodologie des projets de chauffage solaire. Ph. Chouard, E.D.F. (Electricité de France) – Les Renardières.
	Essai d'un capteur solaire de marque . . . en insolation naturelle. Ph. Chouard, E.D.F. (Electricité de France) – Les Renardières.
	Collection de documents decrivant des programmes de recherche francais touchant l'énergie solaire.
	Energies Nouvelles: l'énergie Solaire (document publié par la Délégation aux Energies Nouvelles).
SWEDEN	*Energy Conservation in Buildings R & D.* Swedish Council for Building Research.

USA

Solar Heating Experiment on the Grover Cleveland School, Boston Massachusetts, General Electric Company, July 1974, NSF-RA-N-74-064 (NTIS #PB 239 516).

Design and Test Report for Transportable Solar Laboratory Program, Honeywell, Inc., October 1974, NSF-RA-N-74-118 (NTIS #PB-240-609).

Solar Heating and Cooling Experiment for a School in Atlanta, Westinghouse Electric Corporation, December 1974, NSF-RA-N-74-122 (NTIS #PB-240 611).

Definition Report: National Solar Energy Research, Development & Demonstration Program, Energy Research and Development Administration, Division of Solar Energy, June 1975, ERDA-49.

National Program for Solar Heating and Cooling (Residential and Commercial Applications) Energy Research and Development Administration, Division of Solar Energy, October, 1975. ERDA-23A.

Proceedings of the Workshop on Solar Energy Storage Subsystems for the Heating and Cooling of Buildings, Charlottesville, Virginia April 1975, Depts. of Chemical and Mechanical Engineering, University of Virginia, NSF-RA-N-75-041.

Proceedings of the Workshop on Solar Collectors for Heating and Cooling of Buildings, New York City, November 1974, Dept. of Mechanical Engineering, University of Maryland, May 1975, NSF-RA-N-75-019.

Catalog on Solar Energy Heating and Cooling Products, Energy Research and Development Administration, Division of Solar Energy, October 1975, ERDA-75.

Solar Energy: A Bibliography, Energy Research and Development Administration, March 1976, Vol. I, Citations: #TID-3351-R1P1; Vol. II, Indexes #TID-3351-RIP2.

Solar Heating Proof of Concept Experiment for a Public School Building, Honeywell, Inc., NSF-RA-N-74-119.

Design, Construction and Testing of a Residential Solar Heating and Cooling System, Colorado State University, June 1975, C00-2577-9.

Development of Proposed Standards for Testing Solar Collectors and Thermal Storage Devices, National Bureau of Standards, February 1976, NBX Technical Note 899.

Solar Energy Heat Pump Systems for Heating and Cooling Buildings, Pennsylvania State University, C00-2560-1.

Description of the Solar Energy R & D Programs in Many Nations, F. de Winter, February 1976, SAN/1122-76-1.

USA (Continued)	*Proceedings of the Solar Industrial Process Heat Workshop,* College Park, Maryland, June 28 & 29, 1976, University of Maryland, August 1976, CONF-760655.

SPECIAL FORMAT REPORTS

AUSTRALIA	*Progress Report on the Performance of Three Australian Solar Hot Water Systems.* By H. Salt, CSIRO Solar Energy Studies, SES Report No. 8, September 1976.
CANADA	*Special Format Report (Interim) on the Provident Solar House, Toronto, Ontario.*
	Special Format Report (Interim) on the Mississauga Solar House, Toronto, Ontario.
FRANCE	*Expérimentation des maisons solaires à chauffage solaire d'Odeillo.* F. Trombe, J. F. Robert, M. Cabanat, B. Sesolis, C.N.R.S. – Laboratoire de l'Energie Solaire.
GREECE	*Reflecting Horizontal Solar Collector (Interim Report),* Greek Atomic Energy Commission, Nuclear Research Center "Demokritos" Aghia Paraskevi, Attica, Greece, August 1976.
SWEDEN	*Reporting Format for Solar Heated Buildings with Comments: Summaries of Reports from Three Swedish Solar Energy Buildings,* Per Isakson and Egil Öfverholm, Royal Institute of Technology, Stochholm, September 1976.
USA	*U.S. Special Format Report: Performance of the Sohio Solar Water Heating System Using Large Area Plastic Collectors,* Lawrence Livermore Laboratory, May 1976. SAN/1038-76/1.
	U.S. Special Format Report: Report of the Phoenix Corporation-City of Colorado Springs Solar Heating Project, Kaman Sciences Corporation, June 1976. WA/4578-76/1.
	U.S. Special Format Report: Design, Construction and Testing of the Colorado State University Solar House I Heating and Cooling System, Colorado State University, June 1976. C00/2577-76/1.
	U.S. Special Format Report: Report of the George A. Towns Elementary School Solar Heating and Cooling Project, Atlanta, Georgia, Westinghouse Electric Corporation, July 1976, C00/2628-76/1.

USA
(Continued)

U.S. Special Format Report: Northview Junior High Solar Energy School Heating Augmentation Experiment, Honeywell Systems and Research Center, June 1976, C00/2624-76/1.

U.S. Special Format Report: Project Sage Solar Assisted Gas Energy Project, Southern California Gas Company, August 1976, SE/4691-76/1.

U.S. Special Format Report: Report on the Grover Cleveland School Solar Heating System, Boston, Massachusetts, General Electric Company, August 1976, C00/2626-76/1.

APPENDIX J

1976 MEETING TOURS

Two tours were organized by the Danish hosts for the participants of the Copenhagen meeting. The first was a tour to the Euroc Solar House in Limhamn, Sweden on September 14, and the second was a post-meeting tour on September 16-17 to two solar houses in central Sweden. The tours are described below.

Tour to Euroc Solar House

Euroc "Termoroc" House Limhamn, Sweden	A single-family, 150 m^2 house, employing a variety of energy conservation features to reduce energy requirements by at least 50% as compared to similar residences. The 42 m^2 flat plate liquid collector array is architecturally integrated into the roof. Measurements have been carried out since completion of the building in November 1975.

Post Meeting Tour

AB Östgötabyggen Solar House Linköping, Sweden	An experimental, two-story, well-insulated, single-family residence. The 50 m^2 of flat plate liquid collectors are intended to supply 40-60% of the energy required for space and water heating. The 8m^3 storage tank is located in the garage. Measurements were conducted during the 1975-76 heating season when the house was occupied by a family.
BPA Byggproduktion AB Experimental Houses Forserum, Jönköping, Sweden HL Värmegrund, Consulting Firm	A housing project has been build in Forserum with a heating system which utilizes a thermal foundation to accumulate electric heat and even out peak loads. One of the houses has been provided with 2 solar collector arrays built on the SSW facing gable wall. The 24 m^2 air collector for space heating is connected to the thermal foundation. The 7 m^2 solar collector for domestic hot water uses a water-glycol mixture. Solar energy provides about 25% of the annual space and water heating requirements.